THE SCARCITY-ABUNDANCE RELATIONSHIP OF MINERAL RESOURCES INTRODUCING SOME SUSTAINTABLE ASPECTS

LA RELACIÓN ESCASEZ –ABUNDANCIA EN LOS RECURSOS MINERALES AL INTRODUCIR EL ASPECTO DE LA SOSTENIBILIDAD

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ABSTRACT: The Planet has a large number of concentrations of minerals. However, the low price assigned to these resources and the principles of sustainable mining in the short term may cause limitations in the exploration and extraction of these resources in the immediate future and they affect the supply of minerals. The true accounts of non-renewable natural resources must be completed entering with the non market values associated to its exploitation. The environmental management tools (Exergetic Analisis and Life Cycle Assessment) are instruments to achieve this goal as outlined below.

KEYWORDS: Natural Resources Sustainability, Environmental management tools, Exergetic Analisis, Life Cycle Assessment.

RESUMEN: El Planeta posee un gran número de concentraciones de minerales. Sin embargo, el bajo precio asignado a estos recursos y los principios de la minería sostenible, a corto plazo, pueden producir limitaciones en la exploración y en la extracción de estos recursos, que en un futuro inmediato, sin duda, afectarán al suministro de los minerales. La verdadera contabilidad de los recursos naturales no renovables ha de hacerse introduciendo los valores sin mercado provocados por su explotación que hasta ahora no habían sido contabilizados. Las herramientas de gestión ambiental (fundamentalmente el Análisis Exergético y el Análisis de Ciclo de Vida, aplicados a la producción mineral) son instrumentos para alcanzar este fin, tal como se expresa a continuación.

PALABRAS CLAVE: Sostenibilidad de los recursos naturales, Herramientas de la gestión ambiental, Análisis Exergético, Análisis de Ciclo de Vida.

1. INTRODUCTION

Generally speaking, mineral resources belong to the natural non-renewable resources. However, it still discusses its scarcity; they have a significant economic interest, but differ somewhat from the cycles of the global economy. Moreover, the components of its economy have changed substantially in recent years and have been incorporated the relations with the environment and the social aspects.

The formation of prices, the contribution of technological innovation, strategies for their production and the difficulty of defining its future, are also part of its peculiarities and uncertainties.

2. SUSTAINABILITY USING MINERAL RESOURCES

2.1 The possible reduction of mineral resources

As announced almost all the analysts, the most important factor in future demand for metals and minerals are derived from population growth and the access to new goods that are product of global economic development. However, the majority of world population growth will increase in developing countries, where living standards are low or moderate and the impact of increased population in the total consumption of minerals will not be as high as would occur in situations with an explosive increase of wealth.

Economic cycles, recycling of metals, and other factors, may be second-order controls on the demand for new minerals to more local level. Although the per capita consumption of minerals, as a whole, does not vary substantially with the economic cycle, the progressive trend towards increased global demand has been evident for many decades and is more likely to remain so long more.

2.2 Future supplies of minerals and metals

Mineral commodities produced in large quantities, such as potassium salts or coal, often have a "life of the reserves" of more than 150 years, because it is much easier to calculate and extrapolate the reserves for these products than for producing very local sources, such as the higher unit value. Thus, concentrations of lead and zinc have lives of only 20 to 25 years. In this case, this amount has remained the same since 1950, despite an increase in production from 1.7 million tonnes of lead and 2.2 Mt zinc in 1950 to 3.0 Mt Pb, and 8,0 Mt Zn at the beginning of the new century.

This stability is a dynamic balance between consumption and discovery of new reserves of both metals over the past 50 years. It is obviously much more important and constant effort to maintain a dynamic balance for mineral commodities in shortest life for a very long life. [1] Wellmer and Becker-Platen.

According to Stephen E. Kesler [2], the world population is growing faster than at any other time in history, and consumption of minerals makes it faster than population, as long as new consumers enter the market as a result of its mineral increased quality of life.

Does this mean that we will face a crisis of supply of minerals in the XXI century? If so, we can solve this crisis by providing increased mineral exploration for new mineral resources, and therefore will require a more reliable geological information and easier access to the territory. The answers to these questions should be based on predictions of global demand for minerals in the twenty-first century, along with a better understanding of the relationship between the world reserves of minerals and the formation of deposits.

2.3 Patterns of use of Natural Resources

Natural resources provide numerous goods and services demanded by our society. However, the frameworks within which it operates the valuation of these resources often fail to consider values that had not previously passed by the thought of anyone: aesthetic, recreational, environmental or, simply the existence value.

However there are obvious failures flaws in the markets of natural resources, as noted by Richard F. Kazmierczak [3]:

1. Failures due to common ownership of resources
2. Failures related with externalities
3. Failures in relation to public goods
4. Failures due to failure of the risks and imbalances in the accounts of the property.

Knowing how markets operate and how they fail, we can discuss the strategy of incorporating economic systems. This will use different systems for more complete assessment:

First, one can resort to methods that incorporate the valuation of assets or resources "no market value": Contingent Valuation, Method of Travel Costs and Hedonic Values. It can also use the Cost- Benefit Analysis. The mechanisms to correct market failures mainly consist of the following: controls, regulations, fees, permits, etc.

2.4 Optimal extraction of non-renewable natural resources

The actual experience in production costs indicates that the effects of cost reduction due to new technologies are more important than decline in the quality of the deposits.
Some studies look at long term prices of mineral raw materials stationary and conclude that the shortage will not be any problem at the moment; others conclude that the price over time has a U-shaped and therefore would increase the shortage long term" Jhon E. Tilton [4].

But, 1) In the past century and at times of explosive consumption, has never existed a scarcity problem. 2) The past has shown that trends in the price of minerals is not fixed ... ..."If the society is sensitive about the topics related with the scarce mineral resources to increase investments in geological information to better determine the shape of the curve of accumulated supplies, it could provide many details about the circumstances of a possible reduction in long-term resources " Jhon E. Tilton [4].

Humphreys [5] do not agree with the idea that the social and environmental costs of mining are not included in the price of mineral products. Humphreys's critique is summarized in four points:

1. There is a large or difficult to value the externalities in relation to the creation of a single level of fees, since there are many peculiarities in the mining situations.
2. Valuations are made by experts who have not experienced the consequences of their judgments
3. The internalization of externalities should be a combination of regulations and good governance
4. The trend of increasing membership in the "codes of conduct" or "good practices" is a factor mitigating the effects of regulations and fees.

The world has a wide variety of mineral deposits. However, the low price of these resources and mining conditions of sustainable exploitations in the exploration and extraction of mineral resources, could affect the future supply of mineral raw materials.

2.5 The price mechanism

Prices in general are determined by supply or demand and not by a single variable. However, the production tends to be more stable and predictable than demand. The buying demand in the markets so volatile and almost always tied up in economic activity.

The precious metals and have many features of a competitive market: products are homogeneous, fungible, replaceable, and well distributed throughout the world. Also considered recycled metals and transport prices. Barriers to entry are low: there are good statistics, the markets are reasonably transparent, and information about prospective market is rapidly distributed.

In principle, prices are formed on intersection point of supply and demand curves: if demand goes up or down the supply, then prices go up it will be balanced again. In practice, prices tend to fluctuate around its equilibrium point. P. Crowson [6].

In mineral raw materials, supply, demand, or both are usually in constant change. When resources are exhausted, or when rising production costs, there is an attempt to take control of their prices. In contrast, the opening of new exploitations, the industry demand decline tends to lower the prices of the mineral resources.

2.6 Other dimensions of sustainability

In addition to the economic vision, the social and environmental design the geometry of sustainability. The problem is that valuations of natural capital lost or modified by human actions is difficult to determine because of the unavailability of an economy that fits to “no market values”.

The lack a measurement system to harmonize market values with they have not yet possess, affects the formation of the real prices of raw materials and therefore its scarcity or abundance. One of the latest approaches to the understanding of this problem is the use of "environmental management tools."

3. USING TOOLS OF ENVIRONMENTAL MANAGEMENT MEASURING THE SUSTAINABILITY

3.1 Management tools of environmental quality in mining

It is proposed the use of Environmental Management Tools for an approach to the set of actions that should further implement the valuation of minerals, whereas in its social and environmental aspects linked to their economic viability. Some of them are named below:

- Environmental Accounts
- Best Available Technology
- Study and Improvement of the "Mineral Efficiency"
- Development of protocols on the "Safe Use of Mineral Raw Materials",
- Study of the Improved Production of Minerals and Reduction of Residues
- The Study "Cost / Benefit"
- Development of Sustainable Mining Indicators "
- The "Risk Analysis" applied to environmental decisions.
- "Life Cycle Assessment" of mineral raw materials.

3.2 Use of environmental management tools in the assessment of mining activities

The LCA (Life Cycle Analysis) is one of the most complete and recognized environmental tools. Basically is a procedure of environmental accounting in quantifying properly the adverse environmental effects caused by the products and their manipulation referring to an industrial process generated throughout the life cycle of the product or process.

The international standard, ISO 14040, defines the stages to be met by the LCA execution:

- The definition the objectives and scope of the analysis in order to properly plan the study.
- The analysis of the inventory, in which the system or each of its parts are summarized in graphical form, as a flow of materials and energy and resolving their balance sheets.
- The life-cycle impact assessment, weighting capabilities and summarizing environment impacts, according to a given set of impact categories.

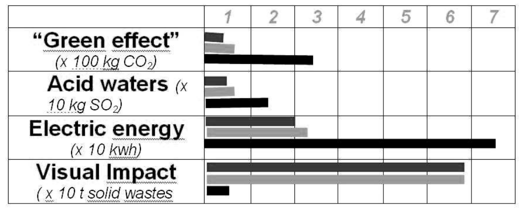

Figure 1. An example in valuation effects on Madrid granite exploitations applying the LCA, Life Cycle Assessment. J.A. Espi.1999

J.A. Espi and Berrezueta [6] have used LCA to assess environmentally several gold mineral deposits typologies according to the Figures 2, 3 and Table 1 schedules.

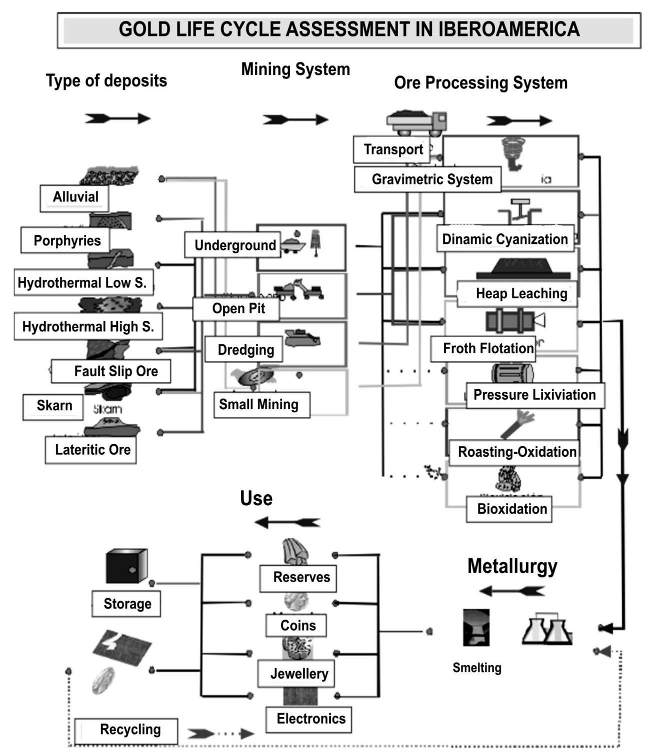

Figure 2. LCA in several gold mineral deposits typologies. Espí y Berrezueta [6]

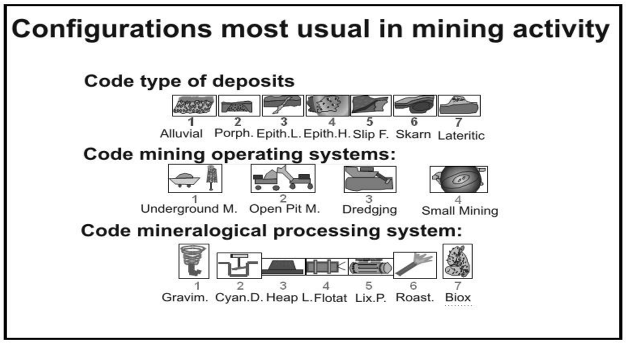

Figure 3. Configurations most usual in mineral gold operations as component of LCA, according types of gold ores. Espí y Berrezueta [6]

	INPUTS and RESOURCES (ton/ore)					
Configurations	Energy (Kwh)	GasOil (l)	Explosives (Kg)	Steel (Kg)	Water (l)	CN (Kg)
(1,3,1)	31,50	6,90	0,00	0,50	300,00	0,00
(1,4,1)	20,50	0,50	0,03	0,50	300,00	0,00
(2,2,4)	26,00	2,60	0,68	1,50	400,00	0,00
(3,1,2)	103,00	5,20	1,30	1,80	500,00	1,20
(3,1,5)	113,00	5,20	1,30	2,00	500,00	0,00
(3,1,6)	103,00	5,20	1,30	2,00	500,00	2,50
(3,1,7)	108,00	5,20	1,30	2,00	500,00	1,50
(4,2,2)	33,00	2,60	0,68	1,80	500,00	1,20
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Table 1. Inputs related with ore model configurations (an example)

And, finally, a summary of the overall effects similar to conditions on production of Acid Waters, Greenhouse Effect, Visual Impact, Energy Consumption and others (Table 2).

Table 2. Summary about the main effects calculated in the exploitation stages and processing of gold ores. Espí y Berrezueta [6]

ASSESSMENT KEY IMPACTS	
Green House Effect	CO_2 liberation
Acid mine drainage (AMD),	SO_2 liberation
Electric energy comsumption	Kilowatts
Mercury added to the biosphere	1 / 3 of that consumed
Cyanide introduced into the biosphere	25% of that consumed
Index related with the **biodiversity**	Minimun level 2
Personal Risk Index in the workplace	Referring to a reference level: open pit mechanized mining

3.3 The Exergetic Analysis applied to the production systems of minerals

Sergio Alan Moreno in his doctoral thesis presented in 2006 at the UPM addresses about use of two environmental tools applied to the most common types of deposits. Its title is "Evaluation of the productive chains of the global metal mining, using innovative tools for environmental management" [7]. The author calculates his environmental qualification using the Exergetic Analysis and the Life Cycle Assessment.

As previous case concerning the different models of gold deposits and their exploitation, Moreno shows that there are procedures that help to determine the true extent of the environmental problems caused by the economic exploitation of natural resources.

The first approach refers to the Exergetic Analysis. Exergy is the maximum amount of work that can be obtained from an imbalance between a system and its environment. The imbalance is that the value of dynamic variable is different for the system and its environment, so is means both are in disequilibrium.

A way of measuring the appropriate use of resources by exergy is the exergy efficiency, which is the ratio of the minimum exergy and exergy consumed in the task. Nature provides us minerals, rocks, water, fuels, in industrial use, which remember us about the need to separate them of its natural components and further purified them. These early stages are profoundly physical energy consumers and energy needed to separate one component of a solution (solid, liquid or gas) tends to be proportional to the inverse of its concentration.

A. Moreno in its application to the mining process begins with separating the genetic models of mineral deposits and relating them with the most common technologies. He called the Chain of Metal Mining. The term “chain” in this case refers to various unit operations related to obtain a product.

3.4 Ore model, methods of operation and metallurgical process

Application examples:
A case could be the different metallogenic types of iron ore deposits:

- Banded iron (BIF)
- Pirometasomatics
- Hydrothermal veins
- For Segregation
- For Replacement
- Exhalative sedimentary
- Oolítics
- Lateritic alteration

The following examples, Figure 4 and 5 show the components of its environmental and energy expenditure:

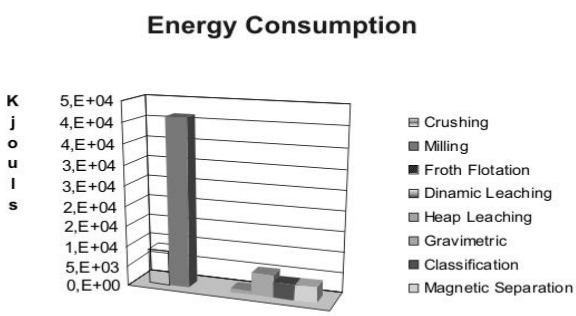

Figure 4. Consumption in kilojoules per tonne processed according to the concentration process

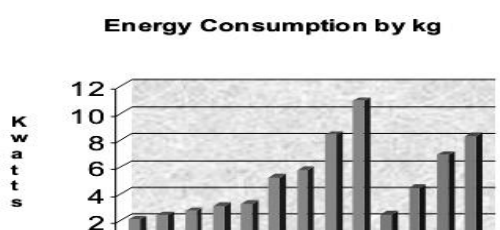

Figure 5. Kilowatts to obtain 1 kg of metal in concentrate for each chains. (Note: the abbreviations of the productive chains means: he first two letters is the metal, the next one, the type of deposit, the next one, the method of mining and the last, the concentration method. For example, CuPUF means copper from porphyric deposit, exploited by Underground Methods, and concentrated by Froth Flotation)

It is very useful a comparison between the calculated energy (exergy) and the actual energy consumed per each process. This indicator of efficiency allows classifying the different productive chains is involved in the process of extraction – concentration of minerals, as then exemplifies for various metals (Figure 6). S. A. Moreno [7].

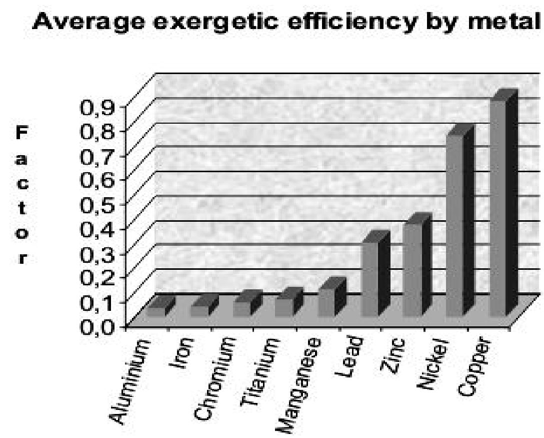

Figure 6. Environmental exergetic average rate for each metal, considering the energy consumption of each chain and the amount of metal produced per tonne..

3.4 Other application: The Life Cycle Assessment (LCA) used in minerals Production

Comparing the method of Exergetic Analysis applied to the processes of mineral exploitation, SA Moreno develops a Life Cycle Assessment with quantitative evaluation using the Umberto software and its ecopoints (Figures 7 and 8). To this account:

Entries (inputs): the consumption of materials, energy and matter flow were obtained directly from the data-mining operation.

Matter flow: calculated based on the quantity of rock needed to move and process each pound of metal to be considered, including stripping if necessary.

Outputs (outputs): the product of the process emissions were calculated using databases from the USGS, NPI (National Pollutant Inventory) and the Umberto software. We have considered both the issues of product consumption of materials, such as those generated in their manufacture.

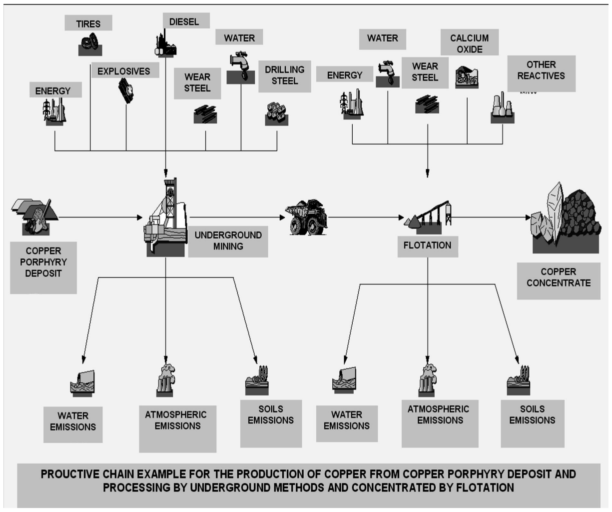

Figure 7. Example extraction-concentration process stages in a porphyry copper ore [7]

Finally, to complete the assessment process of each mineral substance extracted and concentrated will include:

- The impact categories
- The amount of each reference substance emitted
- A weighting factor
- An assessment and normalization factor

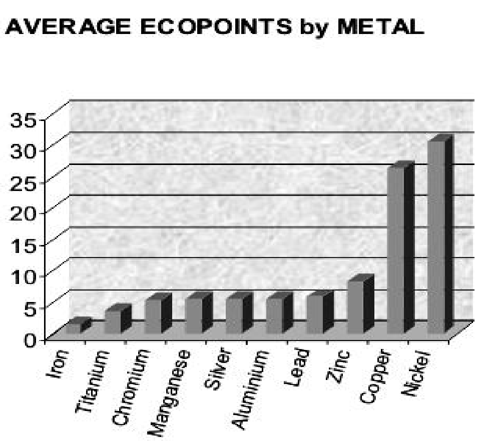

Figure 8. Ecopoints referred to chain metal products, summarized by metal

The author concludes with a comparison of two valuation methods (Exergetic Analysis and LCA) applied to the extraction and processing in the mineral industry (Figures 9 and 10).

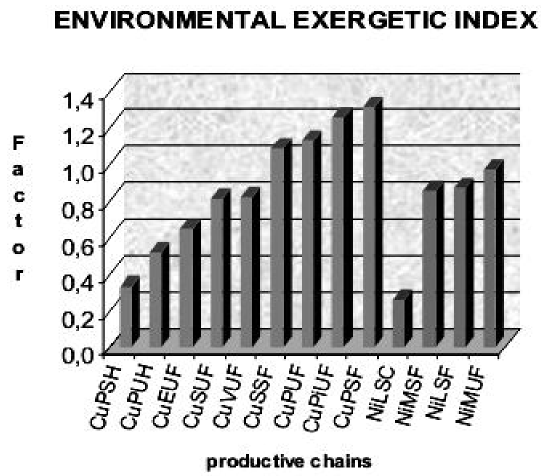

Figure 9. Results of application of Exergetic Analysis and Life Cycle Assessment using several copper and nickel ore types.

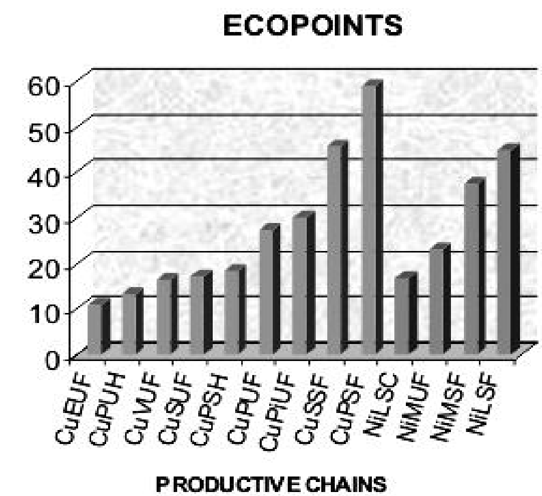

Figure 10. Results of application of Exergy Analysis and Life Cycle Assessment using various types of copper and nickel ores. Exergetic Analisis

As result, S.A. Moreno proposes a cluster analysis as follows:

Group 1: The environmental impacts referring to of mass flow are those that dominate in the: iron, aluminium, chromium, manganese, and titanium.

Group 2: A medium effect between the flow mass and energy: copper, nickel, lead, zinc.

Group 3: Most of the emissions are due to a large power consumption product: silver, gold and PGM

Coinciding with the first approach of the LCA for different types of gold mineralization (Espi and Berrezueta [6] and [8], from the standpoint of sustainable development, the Exergy Analysis shows that the deposits should be exploited to the highest metal content possible, underground mines and in many cases using the low energy consumption, such as hydrometallurgical processes.

4. CONCLUSIONS

4.1 The true scarcity-abundance ratio of a mineral resource

A more realistic relationship between scarcity and abundance of a mineral substance must also be considered within its social and environmental. Therefore, procedures or tools that determine the dimensions that include the three characteristics of sustainable operations (value of "use" and "no market value") must limit the acceptance of resource inventories with a single dimension (economic).

Current technological advances are the result of recent economic crisis, but at the time of prosperity, as the past, the mineral industry has not invest on discovering new types of mineral deposits “green fields”, nor the increase in selectivity in terms of the targets exploration, the incorporation of new areas of the planet and others. Then, the huge size of the processes using poor quality resources and increasing the investment in search of "brownfields" rather than the attractiveness of the project called "greenfields” are the main strategy of many companies.

The series of mergers among large companies is concentrating mineral production in a few hands. This situation is the opposite of a search for a better use of resources. Today, big mining companies are betting on the benefits of easily available resources by opting for tight margins unit generating extraordinary production values multiplied by the great quantities of poor mineral moved.

4.2 Sustainability and Society

To get the sustainability, economic and social benefits that a company generates for the local residents have to be higher than their social and environmental costs. These clear and dimensional benefits must start at the beginning of the project and continue until after closure. To reach this, it must have good projects, managed by experienced companies, where governments also align local and national interests. Bob Elton. Eldorado Controller General [9].

The sustainable yield is associated with good governance. This requires a elldefined regulatory framework, including ights over resources, the delineation of areas of "no exploitation", the rules for apportioning the income of communities and platforms for dialogue.

4.3 The last considerations

The actual perception about the good value used by mankind, especially those who are critical to the Natural Capital has changed as the developing world has risen and the perception related with the effects of population explosion was made visible.

However, the economic value assigned to such property does not always reflect the capital used and hence, often, the price of these goods rather than being a limiting factor or management of its consumption, is an inducement to wasteful use of them. Management environmental tools, now quite varied and specific to many cases, constitute one of the procedures, quantitative analysis and prioritization of action to change the current assessment of natural resources and their true economic assessment.

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