

# A FRAMEWORK FOR THE SUSTAINABLE DEVELOPMENT OF RARE EARTH ELEMENTS MINING PROJECTS

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## Abstract

*The dependence of modern society on critical and/or strategic minerals such as Rare Earth Elements (REEs) is continuously growing due to the numerous end uses and other factors that have been recognized formerly. This paper proposes the adoption of a framework that can be used to guide extraction of REEs under Sustainable Development (SD) principles. The proposed framework includes fundamental elements that contribute to a holistic sustainable platform for REEs. It expands on the existing sustainable development framework and proposes: (a) five basic pillars: economy, society, environment, technology, and (geo)politics, (b) three controlling/limiting factors: policy, governance, and stakeholders, and (c) a number of output quantities to be used in decision making which can also be utilized as SD indicators*

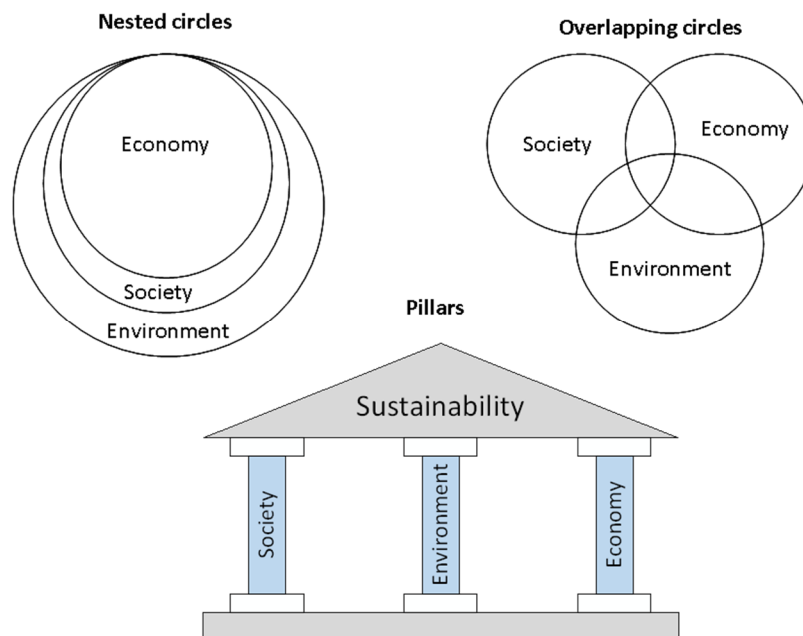
## Introduction

The significance of Rare Earth Elements (REEs) has been recognized in terms of their uses, their trade, the number of recent global initiatives, and the number of related geopolitical events/reports<sup>1</sup>. Some of the findings are the following: China is considered a dominant player in REEs world production; the US, EU and Japan are the major importers of Chinese REEs; China's demand for REEs is increasing; the main end uses of REEs include the energy and defense sectors; REEs applications may provide low cost efficient energy; since 2010 a large number of REE-related initiatives have been proposed within the EU and the US; the substitution of REEs is rare and/or impossible and/or in preliminary status; the recycling potential of REEs suffers by a number of constraints; and a significant number of critical geopolitical events/reports related to REEs have been identified since 2010. In addition, an effort was made to initiate a roadmap for the sustainable mining of REEs. This effort included the stream mapping of the REEs production process, the identification of stakeholders, and the detection of hazards/vulnerabilities of REEs mining<sup>2</sup>. This effort was initiated since until that time there was a complete lack of such a roadmap. The substitution of REEs might be a difficult task, thus turning the problem of REEs substitution into a problem of "minimizing the amount of REEs (...) as little as will give the desired effect" to the end product<sup>3</sup>. The demand for REEs is expected to rise in the future<sup>4</sup>. In addition, the following demand related facts should be considered when someone is dealing with the sustainable development of REEs: (a) the world population is expected to increase<sup>5</sup>, (b) the global Gross Domestic Product (GDP) is also expected to increase<sup>6</sup>, and (c) the largest non-Chinese REEs mining companies are facing critical financial problems a few years after they started their operations<sup>7</sup>. Considering all of the abovementioned information the complete global lack of a framework for the Sustainable Development of REE mining projects would seem a paradox. This paper discusses

the adoption of a framework that can be used for guiding the Sustainable Development of REE mining projects.

### Sustainable Development Schematic Models

The definition of Sustainable Development (SD) was established in 1987 by the “Brundtland Commission”<sup>10</sup>. In 1992, world leaders presented the principles of sustainable development at the United Nations Conference on Environment and Development in Rio de Janeiro, Brazil<sup>11</sup>. During that conference it was agreed that sustainable development consists of three elements: economic development, social development and environmental protection. Twenty years later, during the Rio+20 summit, it was concluded that “*minerals and metals make a major contribution to the world economy and modern societies*”<sup>12</sup>. A “*sustainable path*” was described as “*one that allows every future generation the option of being as well off as its predecessors*”<sup>13</sup>. Different schematic models picturing SD have been proposed: as ‘pillars’, as nested circles, or as overlapping circles<sup>14</sup> (Figure 1).



**Figure 1:** Different Description Models of Sustainable Development

### Sustainable Development in the Minerals Industry

In today’s world the challenge of sustainable mining is critical indeed. This was recognized in 2002 in the World Summit on Sustainable Development (WSSD), the Johannesburg Summit<sup>8</sup>. The Johannesburg summit enhanced “*the contribution of mining, minerals and metals to sustainable development*” and called for actions “*to address the environmental, economic, health and social impacts and benefits of mining*” through the participation of stakeholders and encouraged world community to develop sustainable mining practices. In 2012, the United Nations RIO+20 Conference on Sustainable Development<sup>9</sup> acknowledged that “*mining activities should maximize social and economic benefits, as well as effectively address negative environmental and social impacts. In this regard, we recognize that Governments*

*need strong capacities to develop, manage and regulate their mining industries, in the interest of sustainable development”.*

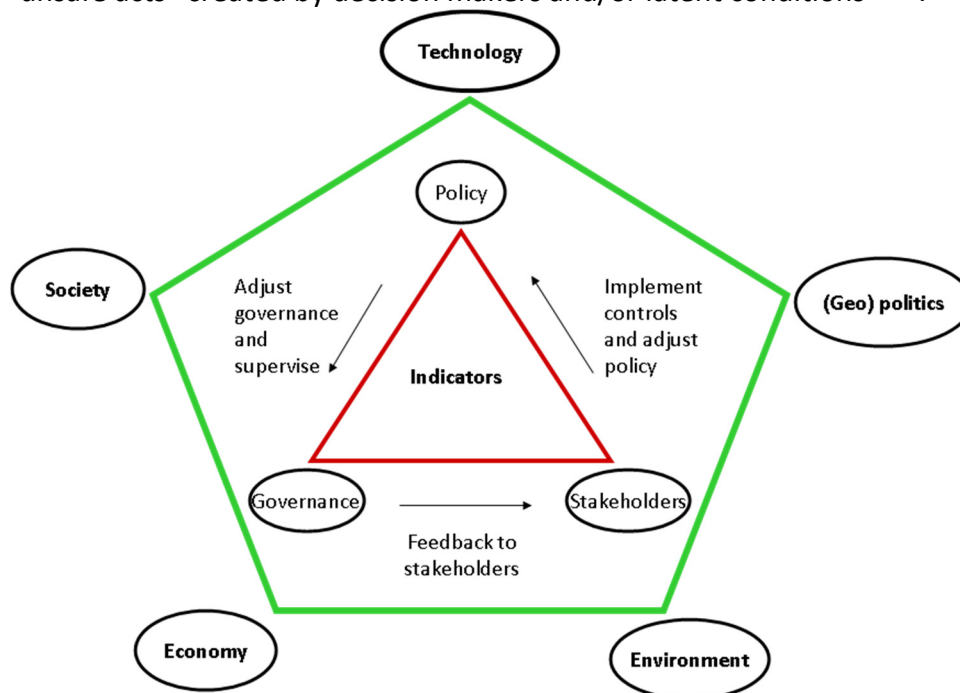
Recognizing the need to move forward and develop REE mining projects in a sustainable manner, a framework for the SD of REEs mining projects is proposed in this paper. This framework is based on the concept of the “overlapping circles”, where the classic three-circle schema is complemented with more sustainability circles as well as a number of controlling/limiting factors/challenges that interact with or within the circles.

### **A Framework for the Sustainable Development of Rare Earth Elements Mining Projects**

Today, the minerals sector and in particular the development REE mining projects are facing several challenges<sup>2,15</sup>. Any recommended action for the establishment of a sustainable mining framework should be within the context set off by the “Brundtland Commission”, the Rio Summit (AGENDA 21), and the Rio+20 recommendations. The proposed framework for the SD of REE mining projects includes fundamental elements that contribute to a holistic sustainable platform for REEs including:

- ✓ Five components represented as circles: economy, society, environment, technology, and (geo)politics.
- ✓ Three controlling/limiting factors: policy, governance, and stakeholders.
- ✓ A number of output quantities to be used in decision making: indicators

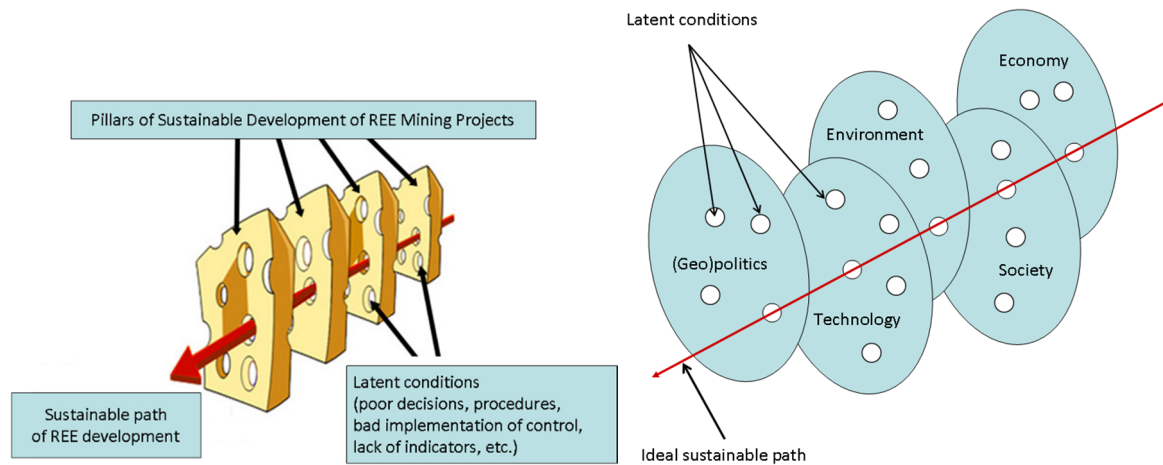
The recommended framework is pictured in Figure 2 and has a global application. To better encapsulate the concept of sustainable path, the “Swiss Cheese” model of accidents was adopted and adjusted to the scope of this analysis (Figure 3, left). Reason’s “Swiss Cheese” model has been proved to be a very useful tool in “accident” analyses: every “accident” is a result of “unsafe acts” created by decision makers and/or latent conditions<sup>16, 17</sup>.



**Figure 2: Sustainable Development Framework for REE Mining Projects**

It is now broadly recognized that accidents in multifaceted conditions occur due to multiple causes that jointly interrelate resulting to the “accident”. If the SD of REE mining project is considered as a desired multifaceted state that may contain several latent conditions then the ideal sustainable path should be determined, which produces the most efficient sustainability level without “accidents”. The ideal sustainable path for the SD of REE mining projects is presented in Figure 3 (right).

The SD models pictured in Figure 1 have a significant weakness: it is difficult to quantify each criterion and its contribution to the overall scheme, since the models do not provide a measurable deviation of each probable sustainable metric entity (i.e. indices, ratios, indicators, etc.) from the ideal sustainable path. As a result, there is no meaningful interrelation/interconnection between the circles of SD and fuzziness is created for decision makers. To overcome this weakness the circles of sustainability should be examined from a different point of view, i.e., the vertical intersection of the circles should be studied (Figure 4).

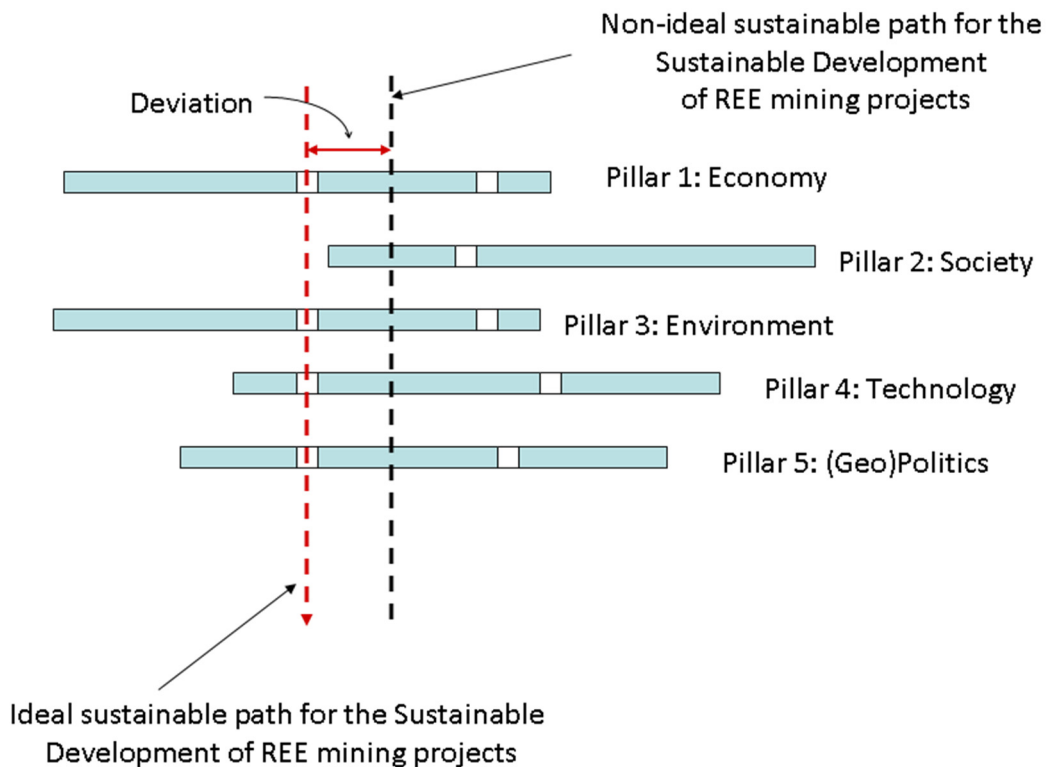


**Figure 3:** Adjusted “Swiss Cheese” and Sustainable Development of REE mining projects (left) and Ideal Sustainable Path of REEs model (right)

The advantages of representing SD for REE mining projects are the following:

- It provides better understanding of the SD interrelated elements.
- It provides a more practical vision of the SD Path.
- It provides the ability to measure the deviation of probable metric entities from the ideal SD Path.
- It provides the ability to decision makers to avoid latent conditions of sustainability by reducing the deviations and make better decisions that will be closer to the ideal SD Path.
- It clearly provides the “go-no-go” option to decision makers of mining projects by adjusting trade-offs between the different SD elements/metric entities.

- f. It clearly sets up the relationship between stakeholders involved in the REEs SD, policy and governance.



**Figure 4:** Vertical intersection of the sustainability “overlapping” circles

### Application of the generic framework in REEs Sustainable Development

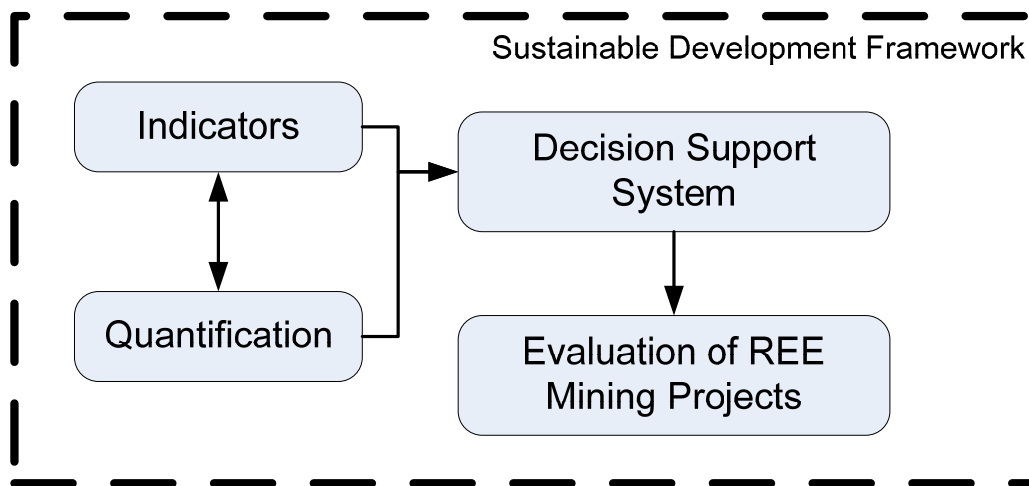
A common expression in management says that “*what gets measured gets done*”<sup>18</sup>. Evaluating REEs mining projects from the sustainability point of view is very critical for decision makers and all stakeholders because it can provide measurable positive or negative impacts of such projects. The best way to perform such evaluations is by using appropriate indicators. Thus, the core of the proposed framework (Figure 2) is based on indicators. The next step would be the development of a decision support system which will incorporate selected indicators and assist decision makers/stakeholders to better assess the impact of any REEs project from the sustainability point of view. A sustainability indicator can be defined as “*a parameter, or a value derived from parameters, which points to, provides information about, describe the state of a phenomenon/environment/area, with a significance extending beyond that directly associated with a parameter value*”<sup>19</sup>. The selection of indicators should be based on the five proposed pillars of Figure 2. The overall process which details how the generic framework can be applied in the case of REEs is presented in Figure 5. The following attributes should be taken into consideration when selecting indicators:

1. The number of indicators is a considerable attribute. A large number of indicators could be difficult to manage and analyze.

2. The word “development” on itself implicates a dynamic process. Thus, the selected indicators shall be manageable and recordable through time.
3. Indicators shall be accessible at a reasonable time.
4. Indicators shall be pertinent to the geographical region exercised.
5. Indicators shall be easy to be communicated and reported.

Selected indicators for each of the five pillars are presented as examples:

- ✓ PILLAR 1 (Economy), Indicator: “Impact of the REEs project into the national/local economy” (income per person during operations and after mining finishes)
- ✓ PILLAR 2 (Society), Indicator: “Impact of the REEs mining project to prosperity in national/local society” (number of jobs created and/or level of unemployment during operations and after mining finishes)
- ✓ PILLAR 3 (Environment), Indicator: “Impact of the REEs mining project to environment” (level of radionuclide activity concentrations during operations and after mining finishes)
- ✓ PILLAR 4 (Technology), Indicator: “Impact of REEs mining project to the local high tech entrepreneurship” (number of high tech business permits issued by national local authorities during operations and after mining finishes)
- ✓ PILLAR 5 (Geopolitics), Indicator: “Impact of REEs mining project to global secure supply of REEs” (percentage-reduction-of Chinese monopoly in global REEs production)



**Figure 5:** The process which describes how the generic framework can be applied in the case of REEs

## Conclusions

In this paper a framework was proposed for the Sustainable Development of REE mining projects. This framework incorporated five basic “overlapping” circles: economy, society,

environment, technology, and (geo)politics. The proposed framework also includes three controlling/limiting factors: policy, governance, and stakeholders, and indicators to be used in decision making. Furthermore, to better encapsulate the concept of sustainable path, the “Swiss Cheese” model of accidents was adopted. Finally, the “overlapping” circles of SD are proposed to be examined from their vertical intersection. This new approach provides a practical vision and better understanding of the SD Path, the quantification of the deviation from the ideal SD path, the “go-no-go” ability to SD decision makers and the ability to avoid latent SD conditions. Finally, it was explained how the generic SD framework can be applied in the case of REEs.

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