Climate Change and Rare Earth Elements Scarcity: From Post-Normal Science to Post-Normal Politics

Essay for the PhD Course «Climate, Media and Politics» (Bergen, November 15th-19th 2010)

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Initial abstract (November 2010)

"Climate change is clearly the environmental issue which has received most attention from scientists, policy makers and the media in the last decade. Subsequently, part of the academic world, and especially the social scientists, also focused on how this issue was represented, which values were at stake, how the discourses framed the issue, etc. One can then legitimately wonder if this huge amount of knowledge produced in the context of climate change could be useful to frame other environmental issues, which received much less attention from the media and policy makers – not to mention the public opinion.

(Hulme2009) acknowledges several ways of looking at the history of climate change - among them, the conclusions of IPCC reports, the increase of knowledge production, or how the language around global warming has changed. Are these indicators relevant in another environmental issue such as mineral depletion? As for the way of framing the debate, can the frameworks he proposes, from market failure to planetary "tipping point", be somehow useful in order to better understand the values and imaginaries of the different participants involved in the debate around resource scarcity?"

New abstract (March 2011)

The paper starts by a discussion of an environmental issue, mineral depletion and rare earth elements scarcity, in which neither the political and national scale, nor the technical promises, seem to be relevant. Consequently, we will advocate that a post-normal approach is needed in the case of the risk of rare earth elements depletion, as it has been implemented in many global warming discussions.

Finally, we will intent to give some insights about how the discussion about mineral depletion, and in particular rare metals, could be useful to climate change discussions, by introducing the concept of «post-normal politics» to cope with the issue, among others, of global injustice.

Key-Words: Global Injustice, Global Warming, Mineral Depletion, Rare Earth Elements

Number of words: 7895
Without abstracts and bibliography: 6992
Introduction

In this essay I have tried to investigate the links between two environmental challenges, climate change and mineral depletion, in order to find both similarities and differences which could help us better understand and address these two issues.

More precisely, I had been asked four more specific questions, that I have tried to address: to focus on one type or groups of mineral; to find some dimension on which the problems are fundamentally related; to focus on the issue of global injustice; and to discuss the question «what can we learn from the discussion of the problem of mineral depletion when we want to understand the problem of Climate Change?».

I have then decided to focus on the group of Rare Earth Elements, as explained in section 1. As for the dimension on which the two issues would fundamentally be related, it appeared to me that it was their affiliation to what has been called the «Post-Normal age», as developed in section 2. In this section, the issue of global injustice is also discussed as a specific insight into the Post-Normal age. Unfortunately, given the very unequal treatment that global warming and mineral depletion have been given by human and social sciences in the last decades, finding perspectives that had been proposed to discuss resource scarcity and not global warming, did not seem as a very easy request to fulfill. I have tried though to address it by proposing the concept of Post-normal politics, that hopefully will contribute to better grasp the numerous aspects of issues at stake in both Global Warming and rare Earth Elements Scarcity discussions.

1. Presentation of the case study: Minerals and Rare Earth Elements

1.1 What is Rare Earth Elements?

Rare Earth Elements (REE) comprise those elements that are part of the lanthanides, with atomic numbers 57-71. Scandium (atomic number 21) and yttrium (atomic number 39) are also grouped together with REE because of their similar properties and their tendency to occur in the same deposits (Kesler 1994). They are by far the most important of the so-called «chemical and industrial metals», along with cadmium and antimony for instance.

![Figure 1: The Periodic Table of Elements, with Rare Earth Elements highlighted in yellow.](image-url)
1.2 How rare are REE?
The term «rare elements» is actually a historical misnomer. Indeed, the most abundant REE, like Cerium, are similar in crustal concentration to commonplace industrial metals such as nickel or copper. As for the least abundant, such as Thulium and Lutetium, there are still nearly 200 times more abundant than gold. What makes their scarcity then is mostly the low probability of finding them in high concentrated exploitable ore deposits.

1.3 Why are REE specific?
Among metals, REE constitute a very specific and interesting case for at least six reasons:

• Although all metals have seen their extraction and consumption raised tremendously these last decades, the raise has been particularly spectacular for REE, and will most likely continue on this path. «Demand for the rare earths in high performance applications, such as magnets, catalytic converters and rechargeable batteries is bound to increase.» (Hill 2011). Up to about 1965, global production of REEs was around 10 000 tonnes per year. In 2010, the demand was about 140 000 tonnes¹, so around 14 more. If we compare with other metals, the raise is quite spectacular. For instance, in the same period (1965-2010) the world production of copper went from 4 million tons/year to around 16 000 million, which is «only» 4 times more.

• REE are indeed now of key importance for various ranges of technology, including smaller sized technology (laptop computers, cell phones, etc.), green technologies (wind power turbines, hybrid vehicles, etc.), water treatment (with the XSORBX technology, developed by Molycorp in order to purify hevily polluted drinking water sources) and the defense industry (cruise missiles, precision guided munitions, radar systems, etc.). (Hurst 2010)

• Although more abundant than many familiar industrial metals, the REE have much less tendency to become concentrated in exploitable ore deposits, and the extraction process is longer, more complex, costly and energy-consuming than for the regular metals (USGS 2002 and Hurst 2010).

• The world's supply comes from only a few sources, and 97% of the world market is hold by China. Consequently, the geological data about REE being very sensitive, they are quite hard to find and not very trustworthy (Hurst 2010).

• Substitutes for the REE are currently inferior or unknown, and the recycling of rare earth is extremely problematic (Hill 2011).

• Apart from the problem of scarcity and depletion, there is a major concern about environmental damages that REE mining causes every year due to lax mining practices – significantly more than with other types of metals – and possible radioactive contamination with tailings containing thorium.

Considering those characteristics, two remarks can be made:
First of all, sustainable management of REE will necessarily be very different from the one of other minerals.
Second, managing REE Scarcity faces two major challenges, systems uncertainty, and very high stakes decisions, which makes it a post-normal issue.

¹ www.mineweb.com/mineweb/view/mineweb/en/page72102?oid=101455&sn=Detail&pid=92730
2. Rare Earth Elements Scarcity and Global Climate Change as Post-Normal Issues

2.1 What is post-normal science?

The concept has been developed by Jerome Ravetz and Silvio Funtowicz to describe situations in which "facts are uncertain, values in dispute, stakes high and decisions urgent" (Funtowicz and Ravetz 1991), and is meant to be opposed to the «normal science», as defined by (Kuhn 1970).

![Figure 2: Three types of problem-solving strategy (Funtowicz & Ravetz 1991)](image)

Post-Normal Science (PNS) can be located in relation to the more traditional problem-solving strategies by means of a diagram (see Figure 2). We see two axes on it, ‘systems uncertainties’ and ‘decision stakes’. When both aspects are small, we are in the realm of ‘normal’, safe «Applied Science», where expertise is fully effective. When either is medium, then the application of routine techniques is not enough; skill, judgement, sometimes even courage are required. This is «Professional Consultancy», with the examples of medicine or engineering in mind. In such cases, the creative element is more an exercise in design than the discovery of facts.

But in recent years we have learned that even the skills of professionals are not always adequate for the solution of science-related policy issues. When risks cannot be quantified, or when possible damage is irreversible, then we are out of the range of competence of traditional sorts of expertise and traditional problem-solving methodologies. This situation is represented on the diagram as the outer band, that of PNS. We notice that the band extends through the whole quadrant, right up to the region where «systems uncertainties» vanish. This feature reflects the fact that if in some policy process the decision stakes are very high (as when an institution is seriously threatened by a proposed policy) then a defensive strategy will involve challenging every step of a scientific
argument, even if the systems uncertainties are actually quite small. ²

2.2 How has PNS been applied to global warming issue?

(Saloranta 2001) states that «the climate change issue well fulfills the attributes needed to belong to the domain of Post-Normal Science» (Saloranta 2001, p. 400) and he proves so by identifying several aspects of the IPCC second report which definitely belong to the realm of post-normal science.

First of all, he recalls that the IPCC report «was compiled through a massive process», involving 78 lead authors from 20 countries. Moreover, «During the process, over 400 contributing authors submitted draft text and information to lead authors and over 500 reviewers were contributing with comments and suggestions.» Consequently, «in this description, one can easily recognize the essence of the ‘Post-Normal’ Extended Peer Community [...]», where, under coordination of the WG I [Work Group I], diversing and different perspectives are welcomed into the dialogue and, at least seemingly, synthesized into a more or less balanced and quality assessed outcome, the WG I SAR. The extraordinary broadness and size of this Extended Peer Community arises evidently from the all-involving nature of the issue.»

Second of all, (Saloranta 2001) identifies a PNS approach in the management of uncertainties of the IPCC. Indeed, the uncertainties taken into account are both epistemological (they are referred to as «surprises», which can be irregular and non-linear responses of the climatic system) and ethical (when the IPCC report for instance acknowledges that the term «dangerous» is value-loaded.)

Third of all, the IPCC is seen as correlated to a PNS approach to the extent that it is goal-driven, towards a «more-effective problem solving». To prove this point, (Saloranta 2001) sums up as follows the findings of (Agrawala 1998): «Though the inputs provided by the IPCC may not have caused decisions to be done, they may have made decision-making more efficient, and that something like the IPCC was an evolutionary necessity for solving the global, complex, uncertain, multi-sectoral and political problem of the climate change.»

These three aspects of post-normal approach, massive collaboration of scientists from different disciplinary and geographical background, management of uncertainties, both epistemological and ethical, and direct contribution to decision-making, have also been pointed out by (Hulme 2007) in a popular article in which sums brillantly the link between Climate Change and Post-Normal Science: «What matters about climate change is not whether we can predict the future with some desired level of certainty and accuracy; it is whether we have sufficient foresight, supported by wisdom, to allow our perspective about the future, and our responsibility for it, to be altered. All of us alive today have a stake in the future, and so we should all play a role in generating sufficient, inclusive and imposing knowledge about the future. Climate change is too important to be left to scientists - least of all the normal ones.»

2.3 Could Rare Earth Elements issues also benefit from a PNS approach?

A key question for us now is whether or not the PNS approach could also be relevant to frame mineral depletion debate, and in particular in the case of Rare Earth Elements. As far as I know, there hasn't been any attempt to apply a post-normal frame to these questions. However, it seems that several features of PNS, if not all of them, are to be found when considering mineral depletion and in particular REE.

(Funtowicz and Ravetz, 1991) identify post-normal science when "facts are uncertain, values in

² Most of the information above has been taken from: http://www.eoearth.org/article/Post-Normal_Science
dispute, stakes high and decisions urgent”. We believe that all these four conditions are met by the issue of mineral depletion, and therefore that it should be treated adequately, using post-normal tools.

**a) Uncertainty**

The importance of uncertainty in the debate regarding mineral depletion in general is acknowledged by many authors, such as (Tilton 2002): “Given such uncertainty, we simply do not know whether mineral commodities 200 hundred years hence will be more or less expensive, more or less available.”

These authors usually acknowledge several causes of this uncertainty:

“The great beyond, however, depends on the race between the cost-increasing effects of depletion and the cost-reducing effects of new technology. The outcome will be influenced by many factors, and is simply unknown.” (Tilton 2002, p. 119)

“In order to be able to assess and/or judge better the question as to future requirements and future availability of metallic resources, we can firstly look at historical examples – i.e. metal volumes produced globally to date – and secondly at expected demand in the future, once the current developing and newly industrialising countries adjust their level of consumption to that of the industrialised countries. Of course, both are likewise comparatively uncertain speculations.” (von Gleich 2006, p.9)

“Such ‘estimations’ and especially the future extrapolations in the next step concerning technical developments, extraction effort and yield rates are naturally highly uncertain.” (von Gleich 2006, p.20)

“Given uncertainty regarding the nature of the “background” environment over longer periods of time, project proponents may argue that it is in fact impossible to accurately assess the implications of the impact represented by a mining project, and may use the absence of existing information as a rationale for not attempting to do so.” (O’Faircheallaigh 2009)

Indeed, the meaning given to “depletion” or “scarcity” can vary greatly depending on the context.

As stressed by (Yaksic&Tilton2009), “Shortages of mineral commodities can arise for a variety of different reasons - wars, embargos, cartels and other market manipulations, natural disasters, accidents, cyclical booms in global demand, inadequate investment in new mines and processing facilities, and resource depletion.”

(Steen2006) identifies four types of limiting factors which are relevant in the debate of abiotic resource depletion:

•”Those based on energy or mass”
•”Those based on relation of use to deposits”
•”Those based on future consequences of resource extractions”
•”Those based on energy consumption or entropy production”

The same rough limitations are identified by The Hague Centre for Strategic Studies: “The bulk of available mineral deposits is not (yet) exploited, due to technological or economic limitations, or because it would require too much energy to do so.” (Kooroshv et al. 2010).

In (Otto 2010) again one can read: “Every mine will close. This may be a result of the deposit being depleted or because economic or social factors make it no longer viable to mine.”

Following these authors, we suggest that mineral depletion could be caused by four different kinds of limitations:
1. Physical Depletion
2. Depletion by lack of energy to go through the mining process
3. Depletion because of excessive environmental impacts
4. Economic scarcity: increasing costs will make mining too expensive

Each one of these indicators enables us assessing one particular threat of mineral depletion. But as it appears, each indicator is in itself relies on many uncertainties, some of them being common to all of them.

Now considering more specifically the case of REE, the uncertainty is reinforced by three kinds of reasons: first of all their geological distribution which makes find them mostly in very low, non-exploitable deposits; second of all the huge commercial interests and geopolitical aspects, which make the few available information not very reliable. Third of all, the uncertainty concerning the life cycle of REE: “One huge problem is that the life cycles for most of these elements [“rare earth minerals and other critical materials”] and remain unknown. That means almost nobody has any overall sense of where the materials go and what happens to them during their lifetime of use”, according to Thomas Graedal, an industrial ecologist at Yale University.³

b) Values in dispute

(Tilton 2002) identifies two paradigm choices, which he calls the “pessimists” those who believe in the “fixed stock paradigm” and the “optimists”, who are convinced by the opportunity cost paradigm (Tilton himself clearly stands for this position).

But even within the “optimist” position, uncertainties remain. Indeed, (Tilton 2002) explores the necessary conditions for an internalization of external cost, the best way according to him to manage natural resources. All the three conditions rely on uncertainties, that we can characterize as being social, political, and technical:

First of all, measurement of external costs, including value people may place on preserving wild landscapes such as the Amazon region. “However, this pessimistic scenario assumes that the true external costs are very high. While such assessment may accurately reflect the values of particular individuals, the extent to which they can be generalized and thus used to represent the values of society collectively is uncertain.” It is very uncertain therefore whether mineral extraction can continue on these regions and be socially acceptable: social uncertainty

Second of all, governments’ will and means for regulation: political uncertainty

Third of all, technological developments: “once the external costs are measured and internalized, new technology must be up to the challenge of reducing these costs over time. Whether this will actually be the case or not is uncertain” (Tilton 2002 p. 16): technical uncertainty.

Challenging the faith in technology: many optimists often take the example of mine depth. “If only”… we could take iron from the earth crust, or “if only” we could extract mineral deposits below 10 kilometers, etc. But one has to notice that progresses in this area are very slow. (Kesler1994) reminds us that “mining does not extend below about 2,3 kilometers in most areas and the gold mines of South Africa, the deepest in the world, reach depths of only about 3,7 kilometers”. More than 15 years later, what is the situation? The deepest mine is still in South Africa, Tautona, with a depth of 3,9 kilometers. That is about 200 meters gained in 17 years. At this pace, we would need centuries before reaching the end of Earth’s Crust (continental crust’s thick usually is between 30 and 50 kms).

³ http://www.innovationnewsdaily.com/gadgets-cost-fortune-precious-110216html-1792/
Other sorts of “values profiles” can be found: (Collier 2010) for instance distinguishes between the “romantics” and the “ostriches”, for whom the solutions to bring to the problem are quite different.

“For the romantics, those who believe we must radically alter our relationship to nature and scale back consumption, this [intensifying scarcities of natural resources and a deteriorating climate] is music: global industrial capitalism is finally getting its comeuppance, drownning in its own contradictions.” On the opposite, for “ostriches”, “if there is to be scramble for natural resources the important thing is to win it.” (Collier 2010, Preface, xi).

c) High Stakes

Since the alarming discourses in the early seventies, popularizes by the Club of Rome, and before the issue of Climate Change emerged and pervaded the field of environmental concerns, resource scarcity was considered a serious threat, would it be because of physical depletion or environmental limitations. One can read for instance in the preface of (Kesler 1994): “At the end of the twentieth century, we are faced with two closely related threats. First, there is the increasing rate at which we are consuming mineral resources, the basic materials on which civilization depends. Although we have not yet experienced global mineral shortages, they are on the horizon. Second, there is the growing pollution caused by the extraction and consumption of mineral resources, which threatens to make Earth’s surface uninhabitable.”

“Scarcity of minerals is an issue that needs urgent attention of policy-makers. It is a complex phenomenon and subject to high degrees of uncertainty.” (Kooroshy et al. 2010)

![Figure 3: The Criticality Matrix](Committee on Critical Mineral Impacts of the U.S. Economy, Committee on Earth Resources, National Research Council)

Somehow this diagram, called “the Criticality Matrix”, from the US Committee on Earth Resources is very similar to the PNS diagram: the supply risk is assessed depending on very uncertain and delicate to assess data, and the impact of Supply Restriction equals the decision stakes. REE being on the top of the arrow of “mineral criticality” they definitely deserve a “post-normal” approach.
d) Urgent decisions

Urgent decisions are needed concerning REE for at least three reasons:

First of all, from a purely geological point of view, certain REE have a very short lifetime. For instance terbium (atomic number 65), a REE which is used as a dopant in calcium fluoride, calcium tungstate and strontium molybdate, materials that are used in solid-state devices, and as a crystal stabilizer of fuel cells which operate at elevated temperatures, as well as in alloys and in the production of electronic devices, is feared to be exhausted very soon following different sources: «known economically workable deposits will be exhausted in 2012»

Second of all, and maybe more importantly, on a geopolitical level, western countries fear that China might keep reducing their exportation quotas, as they have started doing. For instance for this year (2011), «leading producer Molycorp Inc said last week that it expected full-year exports from China to be down 21 percent compared to last year.»

As a result, the United States have already said that they may complain to the World Trade Organization. If they did, it would be an unprecedented and original trial, having to decide whether the territorial ownership of mineral resources is more or less important than the free trade agreements.

Finally, from an environmental perspective, one must remember that the process of extraction and production of REE is quite complex and can lead to major environmental catastrophies if not handled carefully. Several problems already occurred, partly because of the importance of illegal extraction, which would represent around one third of total Chinese extraction.

Conclusion:

Although a post-normal approach never has been applied to mineral depletion issues, nor Rare Earth Elements – as far as we know – it seems that this approach could be as relevant for this field as it has been for climate change.

But the «mode of science» in itself maybe is not enough, and now we shall consider the politics in a post-normal age.

3. How can the debates around resource scarcity help thinking Climate Change further? Global Injustice and Politics in a Post-Normal age

First of all, let us render unto Caesar what is Caesar's, and acknowledge that mineral depletion has been the first step towards a global awareness of planet Earth as a finite world which could need a more sustainable management, way before the first voices worrying about climate change may have been heard.

Second of all, and on a more theoretical ground, we would like to argue that the issues of mineral depletion and REE scarcity have raised several questions that need to be answered, specifically concerning the issue of global injustice and from which the discussion around global warming could benefit.

As stated by (Hulme 2009) there are many ways of thinking about global warming, among which he identifies six specific frames: the market failure frame, the technological hazard frame, the global injustice frame, the overconsumption frame, Climate Change as mostly natural, and Climate

4http://terresacree.org/terbiumanglais.htm
5http://www.reuters.com/article/2011/03/14/us-china-rareearth-exports-idUSTRE72D0VJ20110314
6Idem
Change as a planetary tipping point. For each frame, different solutions are usually suggested. Usually, two wide range of answers are thought about when we bring global injustice and global warming on the table: political answers (if every country would agree on a global carbon tax, then we would reduce our CO2 emissions, and face global warming on a fair level) and technical answers (if we were able to create stratospheric sulfate aerosols, then global warming wouldn't be a problem for anybody anymore.) The political answers, more precisely usually take place in an admittedly transnational frame, but then still relying on the national scale.

We believe that this approach might be outdated, and we would like to investigate something that could maybe become «post-normal politics», in an age of uncertainty, risk, and scarcity, in order to cope with the issues covered by what some call «global injustice.» We will take the global injustice issue as a specific insight inside the Post-Normal Frame, considering that it contributes to the high level of decisions stakes, as well as to the systems uncertainties (just think of all unanswered questions in development economics).

When (Hulme 2009) speaks about global injustice, he actually only refers to the outstanding difference of revenues between developing countries, or «the South», and «developped countries, or «the North». For the sake of this paper, we will identify global injustice at three levels: geographical (North/South, developed/developing countries, but also China/rest of the world, and National/Global), transgenerational (present generations towards future generations), and cognitive (laypersons versus experts).

Before we go further, one may notice that these 3 levels have little in common with the mainstream movements in favor of «environmental justice» which focus usually on the poor, people of colour and indigenous people, inside developed countries (cf. Bullard 2000).

3.1 Global Injustice : South versus North, or National States versus the World?

a) Global Injustice and Climate Change

Many authors have noticed that the GHG emissions are directly connected with the per capita income. Even though the correlation is not absolute (particularly if we take into account the GHG emissions with land-use change, for which countries like Belize or Guyana, though pretty poor countries, rank respectively 1st and 3rd in per capita GHG emissions for the year 2000), it exists in many way. And not only do the richest countries produce more GHG than the developing countries, but they are better prepared to cope with climatic disasters, both for geographical reasons (they are mostly northern countries) and economic capabilities. The consequences therefore are that the countries which produce the least GHG will also be the ones suffering the most from climate change.

The question of global injustice regarding Climate Change has already been quite a lot discussed, and has focused on different aspects, from the question of future generations (Page2006) to the issue of fairness in adaptation (Adger et al. 2006).

(Roberts & Parks 2007) have examined non-cooperation on climate change policy. They argue that in order to understand why nation-states are either willing or unwilling to participate in climate protection policies is fundamentally tied to international inequality and patterns of mistrust between nationstates. They have framed their argument with the idea of the “triple inequality” of vulnerability, responsibility, and mitigation. They further argue that each one of these components is fundamentally tied to larger issues of economic, political, and social injustice in the world-system. They measure vulnerability by incorporating three factors: number of people killed, made homeless, and affected by climate-related disasters, from 1980 to 2002.
About climate change responsibility, (Roberts & Parks 2007) assert that the industrialized world, particularly the United States, is clearly responsible for a disproportionate amount of carbon dioxide emissions and the consequent global warming. They cover four major fairness principles for climate change policy that have been argued for during recent climate negotiations; grandfathering, carbon intensity, per capita, and historical responsibility. Most importantly, the authors argue that in the current policy climate, none of these fairness principles will work alone. Finally, investigating mitigation, they examine the factors affecting the participation of 192 countries. They include the influence of proximate political factors, like civil society pressure, and deeper social and historical determinants of state action, such as narrowness of export base.

“A Climate of Injustice” reminds readers that climate negotiations take place in an unequal world, and that historical legacies have created a hostile environment in which these negotiations take place. (Roberts & Parks 2007) argue that reaching shared perceptions of fairness will be crucial as worldwide consensus and participation is needed to combat this global problem.7

As for the well-known utilitarian philosopher Peter Singer, he sums up the situation of global injustice in adaptation as follows: «Rich nations may, at considerable cost, be able to cope with these changes without enormous loss of life. They are in a better position to store food against the possibility of drought, to move people away from flooded areas, to fight the spread of disease-carrying insects and to build seawalls to keep out the rising seas. Poor nations will not be able to do so much.» (Singer 2002, p. 17-18).

b) Global Injustice and Mineral Depletion

(077910) proposes quite an original point of view on the link between global injustice, mostly understood as the reign of poverty in the countries of the Bottom Billion, and the exploitation of natural assets such as mineral resources : «the countries of the bottom billion have one lifeline: nature. Nature has the potential to lift most of them to prosperity.» (Collier 2010, p. 3). But to one condition, that the magic equation «Nature + Regulation + Technology» would be respected, then leading to prosperity. If one of the terms lack, it's equal disaster. Then, nature and technology without regulation would lead to plunder, while nature and regulation without technology would cause hunger.

So whereas in the case of Climate Change, global warming is mostly seen as a threat towards countries which were already at a disadvantage, in the case of mineral resources their exploitation is seen as a potential benefit for the countries in which the resources have been found.

c) Challenging the national scale

“We have lived with the idea of sovereign states for so long that they have come to be part of the background not only of diplomacy and public policy but also ethics.” (Singer 2002, p. 8)

By this sentence, Peter Singer wishes to introduce the idea that maybe, nation-states are not the most relevant scale to cope with contemporanean environmental issues. He even goes further when he condemns the position of United States – only developed country which has refused to sign the Kyoto Protocol - and states: “Such a situation gives impetus to the need to think about developing institutions or principles of international law that limit national sovereignty. It should be possible for people whose lands are flooded by sea level rises due to global warming to win damages from nations that emit more than their faire share of greenhouse gases. Another possibility worth considering is sanctions.” (Singer 2002, p. 50).

7 Most of the information above is drawn from the book review by Kelly Austin and Christopher Dick, to be found in the Journal of World-Systems Research: http://jwscr.ucr.edu/archive/vol14/Reviews-vol14n2.pdf
Given the extreme unequal repartition of mineral resources, and in particular REE, one can wonder whether the same kind of reasoning could be applied there. If (Collier 2010) does state that natural assets do not have natural owners, he still sticks to the idea of countries as being the ultimate beneficiaries of them. What proposes (Singer 2002) though is rather revolutionary: following his reasoning, what if the United States had to indemnify Chinese farmers after a flood, while China would give, or be forced to trade, about 80% of their REE?

The American perspective on REE though show how far we are from this kind of global vision. In a 40 pages report about REE and China's Industry, (Hurst 2010)'s only concern seems to be “how to ensure REE supply for the United States?” and not even once do they refer to other countries. Consequently, the strategies considered are far from what (Collier 2010) or (Singer 2002) would call “sustainable”, and many would probably say they're just bearing their head in the sand when reading: “building a strategic stockpile of critical rare earth elements capable of sustaining the country for 20 years or more would greatly increase security of supply. Perhaps this is the most important thing the U.S. can do in the near future.” (Hurst 2010, p. 29).

These two examples clearly show that the national scale alone is not suited to face major environmental challenges such as Global Warming and mineral depletion or REE scarcity risk, even when involved in transnational agreements. And maybe the very idea of nation-states is not best suited to cope with global injustice, both on a regional level and a temporal level.

3.2 Present generations versus future generations

The concept of future generations is very often used by GNOs, public organizations, medias, etc. in order to increase public concern over environmental issues, such as climate change or mineral depletion. For instance the Nature Conservancy organization states on its website: «If we don’t act now, we will leave a much larger problem to our children. The good news is that, if we all join in to stop climate change, we can reduce its impact on our lives, on our environment and on future generations.» Lord Puttnam, an ambassador for Unicef UK, also seems to place the issue of climate change as of the utmost importance for future generations: «When world leaders sit round the table in Copenhagen next month to try and tackle what has become possibly the greatest moral crisis of my generation, a unique responsibility rests on their shoulders as they try to decide what kind of world future generations will inherit.»

The idea of future generations is also very important concerning non-renewable resources: what will they do if they don't have any more oil, copper, and of course, REE, by «our fault?»

The «answer» suggested by (Collier 2010) is that at least we leave them something of equivalent value, instead of «selling the family silver». Indeed, it is a «key choice», with different strategies to adopt depending on the given answer, «whether money generated from depleting natural assets should benefit the present or the future. To benefit the present the money should be spent on consumption. To benefit the future it should be saved.» (Collier 2010, p.97).

(Collier 2010) actually proposes an original perspective on sustainability, by stating that «just because the exploitation of natural asset is unsustainable does not mean that it should be avoided. The only sustainable rate of use of a nonrenewable natural asset is zero. But were we never to use any nonrenewable assets they might as well not be here in the first place; the baby has disappeared with the bathwater. So, literal sustainability sets the bar absurdly high.» (Collier 2010, p. 98)

Beyond literal sustainability then, what (Collier 2010) suggest then is a higher rate of savings on revenues from natural-asset depletion, than from other tax revenues, which would be a sustainable management of resources; on the opposite case, spending the revenues from depleting resources on

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8 http://www.nature.org/ourinitiatives/urgentissues/climatechange/

9 http://news.bbc.co.uk/2/hi/science/nature/8374965.stm
consumption would equal plunder, although in a more subtle form than the one occurring when the value inherent in the natural asset is being hijacked by a foreign company or stolen by a corrupt government – which are the most obvious and often only thought of forms of plunder.

Roughly the same position is held by (Waye et al. 2009) when they argue that « mining can be sustainable if revenues that are derived from mining are collected and used to promote sustainable objectives at both the local (community) and national (or regional) levels. » (Waye et al. 2009, p. 151).

If such a reasoning was to be applied to Climate Change it would mean that «just because an activity releases high rates of GHG, it doesn't mean it should be avoided.» it could mean for instance that instead of trying to reduce drastically the GHG emissions, we could try to make the profits out of it serve for public goods, including adaptation.

If the Stern Report has shown that mitigation would actually cost a much less than adaptation, the idea can still be kept in mind when it comes to carbon taxation, and how to use the profits generated by high rates of GHG emissions activities.

### 3.3 The paradox of Post-Normal Politics

(Bourg & Whiteside 2010) advocate for the end of representative democracy, which is, on their opinion, unable to cope with five features of our modern world.

First is our relationship to space: the first feature of nowadays environmental challenges is that they are global, whereas traditional problems, including environmental problems, used to be local. It is obvious if we consider global warming and REE risk of depletion: both would affect all countries and regions, when this kind of issues used to affect rather small areas - the polluted air of a big city like London (acknowledged since the XIIIth century!); a civilization's struggle to keep finding resources (Diamond 2005). Following (Bourg & Whiteside 2010), there is no more possible immediate conscience of my own actions' consequences, and above all of their effects on others.

The second feature of contemporaneaen environmental problems is their invisibility. Traditional degradations of our environment were perceptible to our senses. Now it is very hard, if not impossible, for the citizen to know by himself his own exposure to environmental risks; he therefore would not be able to judge or choose between different public policies regarding environmental issues. In the case of climate change, and although there is a popular confusion between climat and weather, the cognitive complexity is quite obvious. In the case of REE depletion, it is also impossible for the individual to assess the risk of scarcity, as well as to know precisely, at least for now, what kind of metals exactly, and in which quantity, has been used in the new I-Pod she just bought.

The third characteristic of modern ecological problems is their unpredictability. According to the authors, none of the major environmental problems discovered during the second half of the XXth century had been anticipated before: all were surprises.

Even if this assertion is not completely true concerning global warming on a purely scientific level – it had started to be studied in the XIXth century, and the swedish scientist Svande Arrhenius had predicted already in 1896 a doubling of atmospheric carbon dioxide. He also realized the effect would also reduce snow and ice cover on earth, making the planet darker and warmer. Adding in this effect gave a total calculated warming of 5-6 degrees Celsius. However, because of the relatively low rate of CO₂ production at this time, Arrhenius thought the warming would take

10 «Il n'est plus de conscience immédiate possible des conséquences de mes propres agissements et, tout particulièrement, de leurs effets sur autrui.» (Bourg & Whiteside 2010, p. 12)
thousands of years and might even be beneficial to humanity – the important remains: it was not until after World War II that we started seeing it as a possible threat.

As for mineral depletion, it is interesting to notice that most of classical economists, although very much concerned with scarcity issues, just missed it. Thus, Thomas Malthus simply ignores mining and nonrenewable resources, and David Ricardo does not consider the depletable nature of mines, failing to distinguish between nonrenewable and renewable resources. This distinction has started to be highlighted by the Conservation Movement in the United States, in the late XIXth century, and early XXth. But it was not until the Paley Commission, in 1952, that the question of the adequacy of the world's mineral resources to meet future needs has been taken into account by institutions. Both issues then were indeed not properly addressed before the second half of the XXth century. According to (Bourg & Whiteside 2010) then, this situation belies the classical saying, following which « to govern is to foresee » (« gouverner c'est prévoir »). In this perspective then, our elected representatives are not more capable than the lay citizen of anticipating environmental problems to come.

The fourth feature is about our relationship to time, which refers to two main characteristics of contemporaneous issues: inertia and irreversibility. Whatever we do now, global warming will go on way beyond XXIst century, and among the consequences are the irreversible diminution of our available land – the famous ecumene of the Greco-Romans. And all of the measures we could take now in order to mitigate these risks contravene our immediate interests and our lifestyles. We are thus submitted to an original tyranny, the one exerted by immediate enjoyment of nowadays humans on vital needs of future generations. And it appears that « representative democracy is powerless against this tyranny; even worse, it feeds it. »

The fifth characteristic of contemporaneous environmental problems concerns their qualification: we still think massively in terms of pollution, whereas most of the challenges we are facing today must be considered in terms of flows and limits. This distinction is important according to (Bourg & Whiteside 2010) because if pollution problems may be solved by technical solutions, flow increases cannot. The idea that technology alone will be able to save us then belongs to the realm of beliefs.

If (Bourg & Whiteside 2010) actually do not advocate for a disappearance of representative democracy, they do appeal to other institutional processes, some of them involving more directly the citizens, in order to compensate the shortages of representative governance.

11 «Le mode de gouvernement représentatif est impuissant contre cette tyrannie ; pire, il la nourrit.» (Bourg & Whiteside 2010, p. 16)
The paradox of Post-Normal politics would then be that, whereas issues are becoming more complex, more uncertain, less directly discernible by laypersons, etc. they require, at the same time, a bigger and sounder involvement of these same lay-persons in the decision-making processes. Moreover, the «microactions» of each individual citizen/consumer/stakeholder has a more and more important, though hidden, impact on these issues.

For instance, in the case of REE, a democratic debate around the uses of metals would seem to be a first step towards a better management of REE. Maybe the same could be done with CO2 sources: what do we need most, as a civilization, between cheap plane travels, red meat and individual cars?

**Conclusion : Towards post-normal politics to face environmental challenges ?**

Global Warming issues, mixing systems uncertainties and high decision stakes, called for a new cognitive pathway, represented by Post-Normal Science, as acknowledged by many authors (Hulme 2007) (Saloranta 2001). The problem of resources depletion, and specifically REE scarcity, requires not only a new epistemological approach, but also a new way of thinking ethics and politics. If one would define «normal politics» as relying upon national states, in which decisions are made by the people's representatives, then one could also conclude that maybe a new political ideal is needed. The concept of Post-Normal Politics has already been suggested, for instance by (Healy 1999), who defines it as follows: «Post-normal politics thus equates to a thoroughly democratic polity in which state-level political power acts as mediator for a complex web of decision-making bodies, many analogous to extended peer communities, distributed throughout civil society.» (Healy 1999, p. 666-667)
Features of this new frame would include the irrelevance of national states, and the disappearance, or at least the fading, of representative democracy. If Post-Normal Science was relevant to cope with a situation when «the skills of professionals are not always adequate for the solution of science-related policy issues. When risks cannot be quantified, or when possible damage is irreversible, then we are out of the range of competence of traditional sorts of expertise and traditional problem-solving methodologies» on a cognitive level, the same may be said at a political level, as already early suggested by (Beck 1986): not only can risks cannot be easily quantified, but they are too different on a qualitative level to be even compared. This is when we would need post-normal politics.
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