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Beyond sustainability: A restorative approach for the mineral industry

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ABSTRACT

The concept of sustainability has been redefined over the past two decades, with growing realization that simply avoiding most impacts to human and environmental resources is not enough to counter the long-term losses created by current and past economic activities. The production of mineral resources and fossil fuels would seem to be activities that cannot, by definition, be sustainable, but extractive industries provide necessary contributions to society. By holding extractive industries to higher standards than we do today, they can become part of a globally sustainable approach that will benefit society far beyond the sites of resource extraction.

Truly sustainable living in the future can only be accomplished if the current effect of our presence is restorative (net positive impact) rather than just impact-neutral. One way for the mineral industry to participate is for companies to accumulate a capital fund (by saving a portion of the annual depletion) that is used to mitigate damage and restore habitat to a greater extent than would be required to mitigate impacts from current activities alone. This form of sustainability thus becomes restorative.

Restorative sustainability requires that all current impacts be evaluated using full-cost accounting. Global impacts cannot be ignored, and the values of priceless things must be honored by preventing their destruction. With respect to social resources, all stakeholders must have a say, and full disclosure is required. Active acceptance by society over multiple generations is important, and costs incurred to ensure true sustainability must be accepted as a cost of doing business.

INTRODUCTION

The idea of sustainable development is not new. It might be argued, for example, that prehistoric humans unconsciously understood more about sustainable living than do postindustrial humans because of their need to have maintained a closer connection to the ecosystem. In North America, Paleolithic peoples could experience directly the connection between overharvesting of plants and animals and resulting scarcities. Even so, these hunter-gatherers adversely impacted their environment by hunting more large mammals than could be supported by the animals' reproduction rates, and thereby signaled the beginning of

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what is now termed the "sixth extinction" (Kolbert, 2014). It is unlikely that the Paleolithic hunters were aware of the long-term impacts they had, just as many of us today find it difficult to see our own impacts.

As strikingly illustrated by Esri and Jaggard (2014), the planet now houses 7.2 billion humans, and our numbers are expected to increase to 10 billion by 2050. We manage 75% of the land surface, with 40% of the land surface devoted just to agriculture. Of the primordial forests on the planet, 50% have been lost. Only 10% of the land is being protected in some way from some aspect of development. As a result, extinction rates are now 100–1000 times prehuman levels. As pointed out by E.O. Wilson (2014), this attack on biodiversity is an attack on ourselves. We are despoiling our nest through a combination of habitat loss (the leading agent of destruction), the spreading of invasive species, pollution, population growth, and overharvesting.

The cumulative impact of fossil fuel use alone threatens to make the planet less than habitable for many, if not most, of Earth's species, including *Homo sapiens* (Klein, 2014). For example, in 2012, the World Bank acknowledged that we are on track for a 4 °C warmer world by century's end, marked by extreme heat waves, declining global food stocks, loss of ecosystems and biodiversity, and life-threatening sea-level rise (World Bank, 2012a, 2012b). According to Kevin Anderson of the Tyndall Centre for Climate Change Research, 4 °C of warming is incompatible with any reasonable characterization of an equitable and civilized global community (Anderson, 2012). It is abundantly clear that we humans must not only end our reliance on fossil fuels, but we must also undo much of the damage we have already done.

It is because geologists are often in the forefront of directing development that I present here a proposal for accomplishing development that is truly sustainable, and it is because geologists are critical to the success of the mineral industries that I direct this proposal first to mining companies. This is not to say that the proposal is specific to extractive mineral interests; all industries and individuals should be assessing their own sustainability and could benefit from these suggestions. However, it is first necessary to define what "sustainable" will come to mean.

SUSTAINABILITY: DEFINING THE CONCEPT

The *American Heritage Dictionary* (2011) provides one commonly held definition of sustainable: "capable of being continued with minimal long-term effect on the environment." "Minimal" is defined elsewhere in the same volume as "small in amount or degree," which clearly separates it from "zero." This is actually the root of the problem, because there is a widespread disagreement and misunderstanding over what amount, if any, of long-term effect can be accepted. It is becoming increasingly clear that minimal long-term effects, of the degree most people cannot recognize, are still not small enough.

Sustainability as a business concept was elucidated in 1998 by John Elkington (2005), who coined the term "triple bottom line" to promote a way of business accounting that takes into consideration social, economic, and environmental impacts, the "trifecta of society, the economy, and the environment…often referred to as the 'three pillars' of sustainability" (Jarvie-Eggart, 2015b, p. 4). Viewed this way, sustainability can be reached only if social, environmental, and economic costs and risks are quantified, and impacts are managed across the life cycle of development.

Within a substantial portion of the general public, and certainly within much of the environmental community, sustainability is thought of as a goal that, once reached, will ensure that the planet and its inhabitants will be protected forever and that humans will thrive in an equitable and just society. This concept of sustainability goes well beyond that generally held by the business community, but it does roughly describe that vision of sustainability held by the United Nations and a number of nongovernmental organizations (NGOs). Nevertheless, overlapping and conflicting definitions exist, with the result that "sustainability" and "sustainable" often become common buzzwords voiced approvingly by people with little desire to define the concept any further lest they be held to standards that might impact their business plan. As a result, one might conclude that there is no clear understanding of, or consensus around, what constitutes a sustainability objective or standard (Pezzey and Toman, 2002).

Even so, a number of organizations have taken it a step further and attempted to list goals for sustainable development. One of these groups is the United Nations Open Working Group of the General Assembly on Sustainable Development Goals (2015). Building upon a long history of earlier efforts by the United Nations and other organizations, this working group proposed the following 17 sustainable development goals, defined with specific targets, which were adopted in late 2015 (http://www.un.org/sustainabledevelopment/):

(1) End poverty in all its forms everywhere.
(2) End hunger, achieve food security and improved nutrition, and promote sustainable agriculture.
(3) Ensure healthy lives and promote well-being for all at all ages.
(4) Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
(5) Achieve gender equality and empower all women and girls.
(6) Ensure availability and sustainable management of water and sanitation for all.
(7) Ensure access to affordable, reliable, sustainable, and modern energy for all.
(8) Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all.
(9) Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation.
(10) Reduce inequality within and among countries.
(11) Make cities and human settlements inclusive, safe, resilient, and sustainable.
(12) Ensure sustainable consumption and production patterns.

(13) Take urgent action to combat climate change and its impacts (acknowledging that the United Nations Framework Convention on Climate Change is the primary international, intergovernmental forum for negotiating the global response to climate change).
(14) Conserve and sustainably use the oceans, seas, and marine resources for sustainable development.
(15) Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.
(16) Promote peaceful and inclusive societies for sustainable development, provide access to justice for all, and build effective, accountable, and inclusive institutions at all levels.
(17) Strengthen the means of implementation and revitalize the global partnership for sustainable development.

Sustainability Applied to the Mineral Industry

The exploitation of mineral resources and fossil fuels is widely held to be the basis for human development. As such, it is appropriate for all of us, especially those of us who are geoscientists, to consider how fossil fuel and mineral production might actually become sustainable.

Large numbers of publications and institutions (far too many to list here) have addressed sustainability in the mining and mineral production industry (for example, see Auty and Mikesell, 1998; Franks et al., 2011; Grunwald, 2015; Jarvie-Eggart, 2015a; Liebenthal et al., 2005; International Institute for Environment and Development, 2002; Rajaram et al., 2005), and "sustainability" in some form is now a popular target for most major mining companies. A number of companies have established visible efforts to address sustainability in their existing operations, resulting in a reduction of some of the most destructive impacts from mineral recovery and processing, but this does not mean that their definition of sustainability is the same as that of the average person. Mineral producers (and indeed most businesses) have viewed sustainability somewhat differently.

For example, Liebenthal et al. (2005, p. x), building upon a definition first offered by the World Commission on Environment and Development (1987, also known as the Brundtland Report), began by stating that for extractive industries (like mining), "Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs." They expand that definition by stating, "Given that fiscal revenues constitute a major source of net benefits (beyond those of the project financiers or sponsors) obtained from the extraction of mineral resources, the interests of future generations can be protected through the efficient utilization of these revenues for people in the host country." This would seem to suggest that sustainability for mineral producers is not measured by considering the long-term environmental impacts, nor is it measured by ensuring that future generations can meet their own needs, however one might determine that. According to the Liebenthal et al. definition, what is important is to use the money from industry today to benefit people (likely in the short term) who live near the site of extraction.

Auty and Mikesell (1998) presented a slightly different take on the issue. They opened their book with the statement (p. 3): "Our concept of sustainable development requires that the contribution to economic development [from mining] be maintained, both during periods of temporary reduction in mineral exports and over the long run when mineral-producing capacity declines relative to the size of the overall economy. What is required is not the sustainability of the mineral production that initially generates growth, but the maintenance of economic and social conditions for sustaining that growth." They explain further (p. 60) that "Sustainability requires that the *net* [their emphasis] income from the revenue attributable solely to the resource (excluding natural resource capital depletion) be sustained after the resource is exhausted. This requires saving the annual depletion in order to accumulate a capital fund, which by the time the resource is exhausted, will be sufficient to provide a level of annual income equal to the net income generated by the depleted resource." Stated more simply, mining can be considered sustainable if some portion of the revenue is captured (typically through taxation) and used to generate economic activity (of type unknown) that will replace the income generation of the mining operation after the mine closes. Environmental impacts have relevance only insofar as they impact the short-term ability to generate income.

Environmental damages are widely expected to occur in mining, but they are not always included in the cost calculations. When comparing costs versus benefits, environmental damage must be balanced by increased investment if the economy is to be fully sustainable, because environmental damage is, similar to mineral depletion, a reduction of capital. With respect to local (or even national) costs versus benefits, this is relatively straightforward. Mining typically results in point-source impacts that can be measured and mitigated if the resolve is there to meet a high standard, but with respect to achieving true sustainability, environmental standards are too low. For example, Auty and Mikesell stated (p. 63) that global costs (environmental impacts that transcend national borders, such as global warming) should not be included for the purposes of comparing national social costs with national social benefits. Instead, global impacts are more appropriately addressed at the international level and would require "international agreements on how the global social costs should be distributed among nations and therefore added to national costs." Sadly, such agreements are not in place and are not likely in the near future, thus leading to further uncontrolled emissions from all industries.

According to the Auty/Mikesell model, we can ignore global impacts until such time as they are addressed by the international community, which may never occur. Similarly, we can allow environmental damages of many sorts, provided they do not significantly impact future generations, unless the government or those immediately impacted decide the potential damages are

not acceptable. The damages become more acceptable as fewer people live in the affected area. As Auty and Mikesell explained (p. 63),

> "Frequently, environmental costs fall mainly on indigenous people living in mountains or jungles where mines or oil wells are located, while benefits go mainly to those in urban centres. These situations create difficult problems in comparing environmental costs with the benefits of avoiding environmental damage. Medical costs for treating lung disease are very low for villages served only by a first aid station and a shaman, as compared with medical costs in a city with modern health facilities. As usually estimated, the monetary value of life for indigenous people with low life expectancy and low real incomes is only a fraction of the value of life for residents of the modern economic sector."

In this model, environmental damage that does not directly impact urban (frequently nonindigenous) human beings would appear to be afforded little value. Some might suggest that this approach implies a degree of corporate racism.

Preservation of critical habitat for an iconic species, for example, might appear to have little monetary value unless it is connected to some economic activity that impacts urban populations. A good example of the complexity of valuing environmental impacts in such a case might be the Pebble Mine controversy in Alaska (U.S. Environmental Protection Agency, 2014). The Pebble deposit is a large porphyry copper-gold-molybdenum deposit located ~200 miles (322 km) southwest of Anchorage, Alaska. The proposed mine would include both open-pit and underground portions, and the open pit could be 2 miles (3 km) wide and extend to a depth of several thousand feet. Infrastructure necessary to exploit the mine could include a new port on Cook Inlet, as well as a 104-mile-long (167-km-long) service road hosting a slurry pipeline that would cross numerous streams and wetlands. Mine waste and mill tailings would be stored in two large artificial lakes retained by earthen dams, all within a seismically active area that drains to lakes and streams that feed into Bristol Bay. Bristol Bay hosts rich fisheries of several species, including the world's largest sockeye salmon run. Those opposing the mine, reportedly including the majority of people living in the area, point out that pollution discharges of the type commonly seen from mines like this one could significantly damage this world-class resource, impacting commercial and sport fishing in perpetuity, as well as other species in this biologically rich area. Some of the potential environmental impacts can be monetized, and others cannot, making the Pebble Mine proposal a good example why it is critical to consider and value all environmental impacts, and to not discount potential impacts to resources distant from the mine.

Other recent efforts by those in the mineral industry have assigned greater value to at least some environmental damages from mineral extraction, but the bottom line has remained the same: In the opinion of the mining industry, money can only be made if society accepts some amount of environmental and/or human/social degradation. In 2003, for example, the International Council on Mining and Metals (ICMM) committed member companies to implement and measure their performance against 10 sustainable development principles (International Council on Mining and Metals, 2013). The ICMM was formed in 2001 from its predecessor, the International Council on Metals and the Environment, following upon a need recognized during collaboration with the World Business Council for Sustainable Development, which resulted in the development of the Mining, Minerals, and Sustainable Development (MMSD) project (International Institute for Environment and Development, 2002). The ICMM was formed to represent the mining and minerals industry and advance their commitment to sustainable development. It is composed of ~25 corporate members and ~30 mining industry associations. The 10 principles of the ICMM are:

(1) Implement and maintain ethical business practices and sound systems of corporate governance.
(2) Integrate sustainable development considerations within the corporate decision-making process.
(3) Uphold fundamental human rights and respect cultures, customs, and values in dealings with employees and others who are affected by member activities. [Note: This includes efforts to minimize involuntary resettlement and compensate fairly for adverse impacts where they cannot be avoided. No prohibition of such impacts is prescribed.]
(4) Implement risk management strategies based on valid data and sound science.
(5) Seek [not require] continual improvement of health and safety performance.
(6) Seek [not require] continual improvement of environmental performance.
(7) Contribute to conservation of biodiversity and integrated approaches to land-use planning.
(8) Facilitate and encourage responsible product design, use, re-use, recycling, and disposal of products.
(9) Contribute to the social, economic, and institutional development of the communities in which members operate.
(10) Implement effective and transparent engagement, communication, and independently verified reporting arrangements with stakeholders.

Although geoscientists might be most concerned about the long-term impacts, both positive and negative, of their work, businesses have a reason to address sustainability because it also provides significant short-term benefits. As noted by McLellan and Corder (2013), early integration of sustainability considerations into the design of an industrial operation reduces risk on a number of levels. Given that mining companies frequently work in areas that host significant risk because of difficult political, environmental, or social conditions (and sometimes all three at once), applying a sustainability-based design framework (such as described by Corder et al., 2012a, 2012b) can lessen demands upon all five capital types (financial, manufactured, human, social, and environmental). This is not to say that designing for sustainability currently results in achieving an impact-neutral

state, but it does lessen environmental impacts and improve gains in other areas.

Efforts by groups like the Global Reporting Initiative, the Minerals Council of Australia, and the Mining Association of Canada (see Jarvie-Eggart, 2015b) have further defined the responsibilities of mining companies to manage social impacts, engage stakeholders and indigenous groups, conserve biodiversity where possible, plan for climate change, manage mine water and waste, and reclaim disturbed areas at mine closure. Even so, they all acknowledge, explicitly or otherwise, that "sustainable mining" is an oxymoron. It is an oxymoron partly because mineral resources are finite and cannot be mined forever, and partly because the standards to which mining companies are held worldwide allow varying degrees of environmental and social degradation that would not be possible if true sustainability was an absolute requirement. It is for both reasons that the term "sustainable mining" is now being replaced by "responsible mining," which is defined as "planning, operating, and closing mines in a manner that manages specific social, economic, and environmental risks and impacts (or sustainability) at a given operation" (Jarvie-Eggart, 2015a, p. v). Using "responsible mining" guidelines, local impacts are not eliminated, but they are acceptable if they are low enough to allow work to proceed without substantive opposition. Consideration of larger-scale impacts (global warming, regional biodiversity loss, etc.) may be beyond the scope of an individual operator, or they may be deferred to consideration at a later date or by others. The end result is that even if mining operations act responsibly and follow current guidelines, each individual operation still contributes in some fashion to further degradation of the environment.

Kirsch (2010) provided what may be most critical explanation of the developments described here. He states outright that "sustainable mining" is a corporate oxymoron (similar to "clean coal") that is designed to limit criticism and conceal harm. "From the recognition that the mining industry is inherently unsustainable, leaving behind scarred and ruined environments, the industry now promotes itself as practicing sustainable mining" (Kirsch, 2010, p. 92). Kirsch contended that mining companies have emptied the concept of sustainability of any reference to the environment, and instead use the term to refer to corporate profits and economic development that will extend beyond the life of the mine, which is consistent with the Auty/Mikesell model described earlier.

Indeed, leaving behind degraded environments, even if done "sustainably," seems to be standard operating procedure today. Even for mining companies that support sustainable or responsible mining, impacts are limited rather than eliminated, and best management practices typically focus on the performance of a single activity or operation and attempt to control the impacts of that one operation. Impacts to the environment are also cumulative, compounded from isolated impacts of multiple operations (including those that are "responsible"), or from the aggregation and interaction of present impacts with past or future activities that may not even be related. It is these cumulative impacts, be they local, regional, or global, which arguably are the most important, because it is the cumulative impacts that are widely felt (Franks et al., 2009). In the mining industry, for example, mining is often done in areas that were mined before, and that are already contaminated to some extent with acid drainage or heavy metals (see Fig. 1, for example). To hold one modern mining company responsible for cleaning up wastes from past centuries would seem to be unfair and oppressive, but if all of the waste is not addressed in some fashion, how can one justify allowing any operations to continue?

Recent industry efforts, within developed nations at least, certainly have led to the reduction of some of the most onerous effects of resource extraction, but slowing the rate of growth of environmental impact is not enough to solve the problem. As a society, and indeed as a species, we must change our way of living to eliminate our negative impacts on the planet if we want to avoid the worst-case scenarios that have been predicted…and then we must go a step further and undo some of the impacts of the past.

Why Focus on the Mineral Industry?

If natural resources, be they grown, pumped, or mined, are the building blocks on which we construct our human existence, then it is obvious that our use of all natural resources must be truly sustainable in the long term in order to allow our existence to continue. One might be tempted to think that because the mining industry has been responsible for some pretty memorable messes in the past, the mining industry will never be able to reach that goal. Indeed, few would argue that the mining industry has been in the forefront of environmental preservation.

On the other hand, in the case of agriculture, we as a society have accepted that a large portion of Earth's surface has been forever altered to facilitate the growing of food crops and domestic livestock. The widespread clearing of rain forest in the Amazon Basin has triggered public outcry (Wallace, 2007), but the expansion of agriculture in most other places has been an acceptable practice for hundreds if not thousands of years, and it has been responsible for most of the habitat destruction, forest loss, and population growth leading to the present global crisis. We do not usually hold farmers to the same standards that we do miners, but we probably should, because one could argue that the combined effects of their activities on the whole are much greater.

In this paper, I first direct my remarks to geologists and the mineral industry because it is my opinion that unlike other industries such as agriculture, the mineral industry, aside from fossil fuel production, can (if required) transform itself into an industry that is far more sustainable than it is at present. The mineral industry typically works on individual mineral deposits that can be handled as point sources of potential contamination, and point sources are much easier to mitigate. Although large quantities of rock and soil might be disturbed, the disturbance alone is not what would keep mining from being sustainable. Rather, sustainability hinges on how the disturbance is mitigated, how

Figure 1. Acid mine drainage pooling in an abandoned pyrite-rich mine at Wieściszowice, Poland. Elevated metal and acid contents of the water here and in downstream runoff create obvious hazards to local residents and wildlife. Pool pictured here is up to 50 m across.

the pollutants are contained and treated, how the surrounding and overlying ecosystems are preserved and enhanced, and how the products are used. Instead, what is keeping nearly all industries from being truly sustainable is our inability or unwillingness to hold them (and ourselves) to a higher standard.

Challenges Accompanying Poverty and Lack of Development

Artisanal and small-scale mining present a special challenge. It is much easier to encourage sustainable or responsible business activities in developed countries than it is to promote responsible development in settings where poverty and desperation predominate. For the impoverished, options are limited, and resources are few. People in that situation find themselves unable to plan for the future or consider larger-scale issues because of the necessity of focusing on immediate needs (see Fig. 2). This phenomenon is commonly referred to as "hyperbolic discounting" (Mullainathan and Shafir, 2013). Also referred to as "present bias," this happens when individuals overvalue immediate benefits at the expense of future ones. People who are forced to look for their next meal, for example, have little capacity to plan for longer-term needs. Hyperbolic discounting can be observed in the rich as well as the poor, but the poor have no resources to buffer them from the effects of bad decisions or from changes in the environment. In artisanal mines, this is evidenced by environmental and health problems such as the use of mercury to recover gold, the failure to control mine waste and protect water supplies, and the absence of standard safety practices. Sadly, it is often in such cases that engineering and science are most needed but least likely to be applied. It is also in such cases that the sustainable development principles discussed in this paper will have to wait until the artisanal miners are in a position to consider longer-term issues, almost certainly requiring the coordinated assistance of government and business interests.

Challenges from an Inability or Unwillingness to Measure Impacts

A large part of the challenge in assessing sustainability in any human activity and at any location is in determining the relative values of benefits versus costs. In the case of artisanal mining in developing regions, the miners may weigh their immediate

Figure 2. Artisanal miners and their hand-sorted lead-zinc ore in the Altiplano of Bolivia. These miners use only hand tools and have no safety equipment. They also have inadequate water for washing and consequently expose themselves and their families to dangerous levels of toxic metals. Note the children who are present where the ore is being sorted and crushed.

costs (exposure to mercury, for example) against their immediate benefits (feeding their families), but they might discount any long-term costs, even if they were aware of them. The miners may not experience the long-term costs directly, and their need to provide immediate benefits may be overwhelming.

In the case of more-developed regions, some long-term costs are known and regulated, and others might be well known but not regulated. We do not prevent the burning of fossil fuels, for example, even though we know it is a problem. We allow widespread stripping of coal through mountaintop mining in the Appalachians and the stripping of near-surface tar sands in Alberta, Canada—actions that cause profound local environmental damage but that occur where few people reside. We also are about to permit the stripping of the ocean floor for base metals in the South Pacific (Parkins, 2014). In the case of deep-sea mining, hundreds or thousands of square kilometers of unusual seafloor life may be decimated without being seen by residents of the area, solely to provide metals that are readily available elsewhere. All three of these examples illustrate that what is outside of our collective experience is often out of mind, and so unavailable to the exercise of our collective good judgement.

The need to place a monetary value on environmental and social impacts often presents a challenge that cannot be met easily. If we burn all of the oil derived from the Alberta tar sands, for example, and the atmosphere warms a measureable amount as a result of just that activity, what does that really mean in terms of costs to us as expressed in dollars? How can anyone account for environmental damages that fall far outside the limits of the mine site? What is habitat worth? Are we willing to ignore increased morbidity and mortality if we can make money in the meantime? Questions like this sometimes have no answer, but they illustrate quite well the need to judge sustainability by basing our evaluations on full-cost accounting (Bhagwat, 2005; Tietenberg, 1996).

We cannot ignore some impacts when assessing costs versus benefits, just as we would not ignore some portion of the income made by selling our product. However, it is important to recognize that if something is truly priceless, in that it is so highly valued that we cannot attach to it a monetary value, this means we must honor that pricelessness by not allowing it to be destroyed. We cannot defer the consideration of impacts to others or to some indefinite time in the future. Ethical and moral principles, as well as criminal and civil law, demand that individuals accept responsibility for their actions. Collectively or in groups, we should be meeting those same standards.

A RESTORATIVE APPROACH TO SUSTAINABILITY

May (1996) described two forms of sustainability: weak sustainability and strong sustainability. Weak sustainability requires that we sustain the sum total of natural and man-made forms of capital, with natural forms including both mineral resources and environmental resources. In this form of sustainability, natural capital may be traded for man-made capital, which would allow total depletion of an environmental resource if man-made capital is created such that future generations could fulfill their needs (Bhagwat, 2005). As you might expect, significant environmental degradation can accompany weak sustainability. Strong sustainability goes further in that it requires limits on depletion of each form of capital. The existing stock of natural capital must be maintained because the functions it performs cannot be duplicated by manufactured capital. Impacts are allowed to occur, but they should not compromise the ability of the environment to perform its functions. Even so, strong sustainability does allow local impacts that collectively may deplete the natural capital. As such, strong sustainability, in practice, may not be sustainable.

However, because of cumulative impacts from past generations and continuing destructive activities today, sustainable living in the future can only be truly accomplished if we set a goal of making the effect of our presence on the planet restorative (net positive impact) rather than just impact-neutral. Following upon May's listing, this would require a third form of sustainability, one which might be called "restorative sustainability." With respect to the minerals industry, we might call it "restorative mining."

Building upon the basic structure of sustainability as outlined by Auty and Mikesell (1998), restorative sustainability requires more than just avoiding impacts to the ecosystem. It requires that the net impact of any human activity be *positive* when measuring impacts to environmental and social resources, both in the short run and the long run. In other words, both environmental and social resources must be enhanced in the course of the activity. This can be done by saving a portion of the annual depletion to accumulate a capital fund that only will be used to restore some habitat or area that was previously damaged. The capital fund, which Auty and Mikesell would have used solely to generate economic activity to replace the income generation of the mining operation, is instead used also to clean up messes from the past and restore habitat for native species. The total expenditure must exceed that required only to mitigate for planned impacts, so that the state of the environment is improved over what it was at the beginning of the project. This may require the accumulation of a larger capital fund than envisioned by Auty and Mikesell, and it may also make some marginal projects uneconomic, but it is important to remember that money spent on environmental restoration can be justified as a long-term investment in future economic activities. Examples include the reduction of water pollution to aid the restoration of fish stocks and shellfish harvesting, and application of long-term forest management plans that both capture carbon and allow timber to be harvested in the future.

For those who would criticize this approach as being an unfair burden on mining companies that could make their current properties uneconomic or their products too expensive and drive down sales, it is important to remember that raw materials typically make up a very small percentage of the final costs of manufactured goods. Silver, for example, has varied in price over the past ten years from less than $10 to nearly $50 per ounce (http://silverprice.org/silver-price-history.html). The price of silver jewelry did not change at the same rate over that time, principally

because the total cost of a piece of silver jewelry is determined largely by manufacturing and marketing fees. This also is true for nearly all other manufactured goods, which suggests that mineral and metal prices could increase substantially (if needed to facilitate creation of an environmental capital fund), and most people would not feel the impact. If some mines or prospects become uneconomic as a result of this increased financial burden, then it is only appropriate that they not be mined. Weeding out marginal deposits is something mining companies do all the time.

The intent is to use an environmental capital fund in such a way that the restoration that is accomplished can be maintained in perpetuity, bringing that portion of the world into the twenty-first century looking much as it did years before. In this case, the mining operation becomes a vehicle to accomplish restoration that would have been left undone otherwise. Restorative sustainability is thus defined as the capability of an action (like mining) being continued while restoring and enhancing environmental and social resources.

J.B. MacKinnon (2013) makes the case that we live in a "10 percent world." By that he means that because of the expansion of human populations and resulting environmental impacts, what we see today is only 10% of what it once was in terms of other species' diversity, density, and range. He argues that just 14% of Earth's terrestrial surface is protected from human exploitation, along with just 1% of the oceans. Those numbers are misleading, however, because 40% of the world's snow and ice is protected, but only 5% of the temperate grasslands. Similarly, 30% of coral reefs are within protected areas, but only 6% have effective protection from pollution and overfishing, and the number of reefs that are considered pristine is zero.

What we think of as "natural" depends upon what we experienced in our youth. As an example, for many people, the author's home territory (Vashon Island, near Seattle, Washington) appears to be a largely forested and natural rural setting that is home to native plants and animals, and where the streams are clean and the soil is perfect for organic gardening. Most people do not notice the invasive ivy that is widespread and strangling our native trees. They do not notice the septic system effluents that find their way to Puget Sound, nor do they worry about the arsenic that was deposited across the southern part of the island from a now-defunct ASARCO smelter in Tacoma. In reality, the mature forests and pristine beaches of 300 yr ago were very different from those of today, but no one alive today was here to see them, and so we have no appreciation for the amount of damage that our predecessors have done.

Cited as an example of "shifting baseline syndrome" (Pauly, 1995; MacKinnon, 2013), the understanding of what it means to be "natural" has shifted with each new generation as the world has changed. Over a period of time, we collectively have forgotten what the world used to look like. Even in our short lifetimes, we can observe significant environmental changes and losses that we mourn, but over the course of several generations, reality is so altered that what appears undisturbed to one generation bears no resemblance to the same locale just a few generations before. Thus, our goal for sustainability should not just be preservation of the status quo, but rather a return to an earlier state, one that predates our present world. As MacKinnon (2013, p. 149) eloquently states, "…other species don't only have the capacity to inspire our imaginations, they are a form of imagination. They are the genius of life arrayed against an always uncertain future, and to allow that brilliance to wane out of negligence is to passively embrace the death of our own minds."

How Sustainable is Restorative Sustainability?

If environmental and social resources are intentionally enhanced, is it possible to simultaneously enhance financial resources? One widely criticized aspect of capitalism is its insistence on making a monetary profit at the expense of other forms of capital, and the larger the profit, the better. The goal of making a profit would seem to be at odds with the whole idea of sustainability, and certainly at odds with the desire to enhance environmental and social capital.

To focus on immediate financial gain is a short-term approach that ignores the larger picture and the longer history of our place in the system, as well as our impacts on others and future generations. To save the planet and ourselves, we must focus on the long term. Profits can be maximized when the best possible social and environmental performances are produced, and profit maximization over the long term does not require (and is often undermined by) profit maximization in the short term (Henriques, 2005). However, maximization of profit and economic growth are not the primary goals; what is important is how the activity in question achieves benefits, who benefits, and to what purpose, and how any harm that is planned can be avoided or mitigated.

Consideration of both short- and long-term impacts before undertaking a venture forces stakeholders to consider their actions in a broader sense and leads to creating something akin to a "circular economy" (Ellen MacArthur Foundation, 2012). An economy that is circular is an economy that is restorative by intention. It aims to rely solely on renewable energy, and it minimizes, tracks, and eventually eliminates the use of toxic compounds, eradicating waste through careful design. This concept goes beyond the production and consumption of goods, because it also seeks to restructure how goods and services are used and the relative value of these goods and services. As such, circular economies differ from linear ones in that the typical resource-product-waste stream is transformed into a resource-product-resource stream. Cradle to grave becomes cradle to cradle (McDonough and Braungart, 2002; Sackett, 2012, this volume).

The circular economy concept is patterned after living systems and follows the idea that if you want to design an industrial activity that is sustainable and restorative, look to nature for examples (Kannarath, 2014). Obvious solutions are sometimes the ones that are the easiest to overlook, and inspiration literally can be found in your backyard.

DESIGNING FOR RESTORATIVE SUSTAINABILITY

With respect to mineral production, it may be difficult to see how the circular economy concept could apply. Unusable waste is generated in significant quantities, and some mineral products (such as agricultural minerals and quarried stone) are mined with the intent of using them once. If one instead considers the larger economic picture of a community or a region, it is possible to see how some industries can be accepted as waste generators if their negative actions are mitigated through a combination of their positive actions and the positive actions of others.

In order for sustainability to be attained at the community level, it is necessary for nearly all entities in both business and government, and all individuals, to review their actions and alter them for the sake of the public good. How successful the community will be at becoming truly sustainable is hard to predict. The conditions leading to failure would appear to be more common than the opportunities for success, but what can be predicted with confidence is that failure is certain if only a few people try.

Toward the goal of maximizing the potential for success, some general guidelines for restorative sustainability are presented below. Critics might note that most of these guidelines also apply to sustainability that is not restorative, and some of them apply to much less ambitious development protocols. It is true that these guidelines can be applied to any human activity at any level, but they are designed here to apply first to extractive industries. Industries with less impact on the environment may be able to meet these guidelines more easily. On the other hand, industries with more diffused impacts, such as negative impacts that are distributed throughout a larger population (as might be envisioned for the tobacco industry, for example), may have a harder time justifying their actions.

Critics might also note that these guidelines reproduce some already listed by the ICMM (2003) and other organizations. Clearly, a list like this one is not unique to this paper, but these guidelines are restated here (some emphatically) because of their increasing importance. This list also is not all-inclusive. Recommended additions to the list and constructive comments are always welcome.

General Guidelines for Restorative Sustainability

(1) With regards to social/human resources, all stakeholders must have a say in the creation, design, and effective completion of the economic activity, and social justice must be guaranteed at all levels. If one stakeholder is disenfranchised, intentionally or otherwise, the success of the venture is endangered. Similarly, working conditions and provisions for health care and other benefits must meet standards that ensure long-term viability. Without community cohesion and project ownership (in some form) by all stakeholders, sustainability is a mirage.

(2) Cultural, political, and religious differences between stakeholders should not impact the effectiveness of the overall project. Such tensions may exist, but if the project is designed to generate some form of activity that benefits all and is structured to honor all parties and provide them with appropriate degrees of control, while facilitating environmental restoration to benefit future generations, the opportunities to work together are maximized.

(3) For all stakeholders to be effective decision makers, it is necessary for them to be educated in the nature of the venture, and full disclosure of the environmental, social, and economic impacts and benefits is also necessary. Put simply, everyone needs to know everything. This level of transparency might be considered unprecedented, but it is also good public policy. For the democratic process to function, an informed electorate is required. Sustainability requires everyone's understanding and approval.

(4) Sustainability also requires ownership and acceptance by society over multiple generations. As such, instruction in restorative sustainability should be a fundamental part of elementary education so that successive generations continue and expand the mission of restoring the planet. It should become as automatic to our children as looking both ways when crossing a street.

(5) Primary to the concept of sustainability in any form is the value of priceless things. We can play the game of assigning present-day costs to future environmental or social degradation and accounting for those impacts in our business plans, but so many of those impacts cannot be assigned a cash value. What is the value of, for example, 1 km^2 of polar bear habitat? If agricultural land is forever contaminated by mine wastes, what is that worth? How much does one charge for a single Monarch butterfly if that iconic species is in irreparable decline? If these things are truly priceless, then perhaps we should allow no losses of any kind.

(6) Maintaining biodiversity is the "first, do no harm" step, but the goal is to both expand habitat and increase biodiversity. Exchanging damage in one area for an equivalent amount of restoration in another is simply not enough. As such, by definition there is no such thing as an insignificant negative impact to biodiversity.

(7) Regional and global impacts, such as anthropogenic climate change, cannot be ignored at the local level. Each new activity should be carbon-neutral at the outset (or as close to it as possible) and carbon-sequestering shortly thereafter, so that human activities in total become a carbon sink. One way to accomplish this is to make all energy sources renewable, or, until they can be renewable, mitigate their use by creating permanent carbon storage gains elsewhere. Reforestation might satisfy some of this requirement, provided those gains are maintained in perpetuity. The goal is to reverse climate change, rather than just plan for how to do business when it arrives.

(8) Benefits and costs must be measured using full-cost accounting. Regional and global impacts must be

counted in the same way that local impacts are counted, even if impacts are dispersed and not immediately felt at the local level. The absence of an international vehicle to address global warming, for example, is not an excuse for ignoring it at the local level.

(9) Additional costs incurred to ensure restorative sustainability have to be an accepted and normal cost of doing business. If the added financial burden on a project is such that it does not allow sufficient after-tax profit, then the project is not viable and should be abandoned. Just as it is not ethical now to make money at the expense of others, so is it not acceptable now to make money at the expense of our future.

(10) For manufacturing operations, recycled or renewable raw materials should comprise as much of the feedstock as is possible, and all manufactured goods should be designed to be fully recyclable. In the case of mineral production, or indeed for any exploited natural resource, the utmost priority should be to reduce, reuse, and recycle. Metals and minerals that have been mined in the past can be recovered from waste streams and through recycling. Before looking anywhere else for resources, look in the garbage.

(11) Simple conservation is the easiest and fastest way to save money and eliminate impacts. Our future will be defined in part by what we choose not to do, rather than just by what we choose to do. There are plenty of opportunities to make a positive impact by making no impact.

(12) Local, regional, and federal governments have to set policies and require measures that address sustainability and that exceed current regulatory demands. Collectively, we must hold ourselves to a higher standard. This will entail some degree of short-term sacrifice, but we cannot let politics or short-term economic interests get in the way of our future.

CONCLUSION

The definition of sustainability, and our realization of the need for it, has advanced over the past 20 yr. It has become increasingly apparent that simply minimizing environmental and social impacts for any economic venture (and even for individuals) is not enough to compensate for the damage we are doing now. It is also clear that making all of our current activities impact-neutral will require levels of participation and cooperation never before achieved by human beings on such a scale. To be successful, the targets we set must be higher; impact-neutrality is not enough to undo the mistakes of the past.

It is for that reason that we must fashion a future that is both sustainable and restorative. Restorative sustainability requires that we conduct our business in such a fashion that both social and environmental conditions are improved over what they are now. In order for that to occur, we must account for benefits and costs using full-cost accounting, assessing, and mitigating for all impacts whether they are local or global. We must design our activities to include provisions for the expansion of wild habitat and to increase biodiversity. We must honor and involve all stakeholders by respecting their cultural and religious differences, and we cannot allow short-sighted political or corporate demands to undermine long-term success. Long-term success also demands stewardship by multiple generations, requiring changes in education and social/corporate structure so that all of us are aware of our impacts and our responsibilities. It is not ethical to make money at the expense of others, nor is it acceptable to make money at the expense of our collective future. Lastly, our governments must set policies that require restorative measures exceeding current regulatory demands, and we as citizens must support those efforts for our good and for the good of our children.

Humans today have access to the collective intelligence and technologies of all the world's cultures, as well as thousands of years of experience, from which we can craft a lifestyle that will allow us to survive and to undo the effects of our mistakes. By setting a goal to restore some of what we have lost, we will not just stop the decline of the natural world, we will reverse it. Our children and their children will live in world more like that of our parents' or grandparents' childhood, where they can experience firsthand the wonder and the beauty of the planet on which we live. To quote J.B. MacKinnon (2013, p. 215), "All it will take is a wilder way of being human."

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Notes

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