ACTUALIZING SUSTAINABLE MINING: "WHOLE MINE, WHOLE COMMUNITY, WHOLE PLANET" THROUGH 'INDUSTRIAL ECOLOGY' AND COMMUNITY-BASED STRATEGIES

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Summary

Asking the question, "What do the world's leading corporations and cutting-edge practitioners of sustainability put forth to guide a given mine site for planning and action toward 'sustainability'?", this paper explores the spectrum of methodologies and mindsets in available literature, then constructs an example for the large near-closure facility at Kennecott Utah Copper. Values, opportunities and constraints spring from physical, unutilized byproducts, from critical ecosystems and wildlife populations, from location relative to those ecosystems and proximate communities, and from the political will to perform adequate feasibility investigations. Patience, determination and thoroughness are imperative.

Identifying most productive and, simultaneously, most protective and restorative, practical methods to approach 'sustainability' has become a central mission of industry and business, worldwide. A survey of recent international initiatives finds no single approach that establishes either a readily adaptable methodology or an appropriate set of 'attention' points, or agenda, to guide individual mining operations at specific locations toward the elusive but essential goal of 'sustainable' mining. Untying this convoluted knot of contending factors requires willingness to recognize and work within ecological constraints for community long-term needs. Occasionally, the task requires the sword of Alexander the Great.

Through integration that is unflinchingly honest ethically, culturally, economically, ecologically and scientifically, fully cognizant of place and community at whatever scales are of greatest significance, and integrative of both problem-response and opportunity, we may envision a mineral extraction and beneficiation future that achieves the best, most nearly sustainable, results possible.

Industrial ecology (IE), with its clear emphasis on community, ecosystems, and sustainable economic stimulation, presents a sufficiently broad and adaptable discipline to facilitate planning and management toward sustainable mining. The creation of sustainable jobs encapsulates IE's analogy to the niche survival strategies of organisms in nature. Open to common-sense recognition of faults and opportunities at appropriate scales, IE is less a discipline or prescribed methodology than a mindset, willing to be rigorously scientific when science is imperative, but also willing to exercise "art" when creativity or community engagement are needed. IE is also capable of future-looking compassion for peoples and nature.

Looking beyond what has occurred to date, the case of Kennecott Utah Copper provides ample illustration of *possibilities* for community economic development, environmental management, and significant initiatives beneficial at regional and planetary scales, to become recognizable as deserving of the label, 'sustainable.' Through what this researcher terms "whole mine, whole region, whole planet" thinking, strategies become visible and subject to serious consideration, presenting a path to best possible accomplishment in mining. Constituting a maximal broadening of mining's "traditional" scope, the integrative approach proposed here is the 'paradigm shift' being made by many other industries around the world. In aggregate, these steps are the only hope for avoidance of environmental, social and economic risks that threaten to curtail resource development and impair mining companies' 'social license to operate.'

Mining's Growing Challenges and Emerging Opportunities

As one of the world's most enduring and dominant forms of resource development, mining is a necessary activity whose history is fraught with difficulties, many of them avoidable. Although some have clearly been brought on solely by mining-related practices, many others are the results of long term contextual changes. Population growth has not only 'grown' markets for mineral products, but has also brought communities into conflict with the health and environmental effects of mining. Air pollution, water contamination, waste rock and tailings, abandoned mine shafts, pits and prospects, all have created physical dangers to people, wildlife, and habitats for both. Despite the incontrovertible facts about mining's creation of more wealth per unit area than any other extractive industry, mining's history is filled with legacies of scarred and toxified environments and communities, often with residual economic benefit to the local economy that is disproportionately modest compared to wealth removed to a distant corporate headquarters.

Outright disasters are too numerous, including tailings dam failure at a Spanish mine; emerging acid drainage from the infamous Tri-State Tar Creek (OK, MO, KS) lead-zinc mines many years after closure; countless cases of ground subsidence, natural surface waterbody and aquifer poisoning of widespread effect; and community economic collapses due to sudden mine closures for various reasons, leaving disrupted or displaced indigenous populations. The almost complete loss of forests, native vegetation and soil productivity in some areas has so reduced productivity of lands that they remain essentially vacant or subject to intense economic depression. Of the list of severe U.S. environmental cases nominated for 'Superfund' listing, a considerable number are mine sites, some of relatively recent origin, belying the idea that technology alone can prevent such problems, or that regulatory measures will not allow them to occur. Assessment, remediation and reclamation of these sites amount to such an enormous cost burden as to be, arguably, one of the primary elements of a growing environmental debt facing future generations.

As communities have not only grown around mining areas (partially due, in many cases, to minerals-generated wealth) but also have become better educated and more able to access information from around the world, resistance has grown to mining. An activity whose hosting might be very attractive to communities and nations, were it not for this almost unparalleled trail of historical damage and irresponsibility, has caused even reputable, responsible companies to face organized opposition and litigation, or even denial of access to resources. Perennial cries for reform of the 1872 Mining Law have echoed through the halls of Congress, and continue to do so.

Global and regional emerging environmental concerns compound these local problems. Macro-scale impacts have long since become visible, however difficult to distinguish mining-caused phenomena from the effects of other industries and human activities.

- Acid deposition: Airborne acid from fossil fuel combustion and smelting-refining have reduced the biological productivity of whole regions, as in Appalachia, though blame for this can only partially be placed at the door of the mining industry.
- Energy and climate change: Mining, beneficiation and related manufacturing and materials transport, however, clearly constitute one of the most energy-consumptive of all human activities. Consequent global climate change, caused by accumulation of heat-trapping carbon compounds in the atmosphere from fossil-fuel burning since the Industrial Revolution, is now recognized sufficiently as a universal threat that it demands action through international agreements and national policies now under consideration. Russia's signing of the Kyoto Climate Change Agreement will, inevitably, press companies operating in the international arena to comply with elevated expectations for greenhouse gas reductions, and will create mechanisms to reward significant reductions and offsets.
- Wealth maldistribution and social unrest: Inequitable income distribution has plagued economies throughout the world. Precipitous loss of jobs after mine closure or rapid automation has left many areas destitute, desperate for employment alternatives. Developing nations, particularly, have been unable to escape both the specter of social unrest accompanying unemployment and income maldistribution and corollary political instability.

These pressures loom as mining's primary obstacles unless accepted and embraced as the opportunities that they are, or may become. These challenges should *inform planning for efforts to approach sustainable mining*, defining opportunities as surely as they highlight recurrent problems. Much more than "making lemonade when given lemons," the mindset changes inherent in our collective responses are keys to quality of life at all levels, at all scales, from remote "outback" to most dense urban complex. Everyone needs the products of mining, commodities needs that are difficult to envision diminishing in fundamental ways, regardless how individual products and lifestyles may shift with technological and cultural changes. Metals and non-metals materials from the earth make up the preponderance of our infrastructure, buildings and functional systems. Even were cultures worldwide to become so restrained in consumptiveness as to approach the asceticism of sequestered hermits, and resource recovery were capable of 'recycling' major proportions of key resources, total population numbers promise ongoing growth of demand for these materials for many generations.

"Buffers" physical, cultural, socio-economic, regulatory and environmental, are all precarious if not practically gone. Constraints to mining are not only more visible, but also converging. Population growth increases probability of proximity to a mine, smelter or minerals-related industrial activity, bringing communities into the realm of both benefits and possible deleterious effects. Global population reached one billion in 1804, as the Industrial Revolution was building up steam, figuratively and literally. The second billion was not reached until 1927; the third, 1960; the fourth, 1974; the fifth, 1987; the sixth, 1999. Projections cannot be certain, but they assure us that the seventh billion will be reached around 2012; the eighth by 2026; and the ninth by about 2043 (*NY Times Almanac 2002*, p.472). The regional nature of this growth places most of the increase in East, South and West Asia, Africa and some parts of Latin America, areas also struggling to emerge from crushing poverty. These are also areas where many mines are planned or active.

Even among the most advanced of national economies in rapidly-growing areas, communities and their environments are brought into conflict with industry, including mining, more frequently than ever before. China's relatively unregulated coal mining industry experiences more than 4,000 deaths per year in the struggle to provide fuel for increasingly affluent areas. Almost everywhere, ecosystems, habitats and wildlife dependent on them are made more vulnerable by competition from populations, relegating extractive and energy-intensive resource industries to positions closer to critical environmental and economic margins. Mining finds itself, increasingly, 'between a rock and a hard place.'

Rising affluence among burgeoning populations compounds implications for demand of minerals and energy from mining, as well as tightening constraints on how these activities are carried out. As China, for example, the world's most rapidly-growing large nation, multiplies its standard of living at unprecedented rates, the quantity of resources required for this 'progress' imposes corollary implications far beyond China's immediate vicinity, global warming acceleration due to coal-dependence being only one example. This is true for environmental variables, for international investment, and for political systems that must maintain economic circumstances conducive to resource development, however increasingly this development is marginalized. As China's electricity consumption, now averaging per capita annually about the amount required to power a single, 60-watt lightbulb for 30 minutes each day, approaches European or even US levels (more than one hundred times China's average), constraints are likely to become more demanding of exercise of forethought, planning and socio-economic and environmental responsibility.

Cultural, social and information-driven changes are exerting profound pressures on extractive industries, moreover. Information access is opening environmental and socio-economic awareness globally, giving rise to movements, information and public education campaigns, as well as conduits for disinformation and folklore at large scale, with rapid dissemination. Environmental education has rightfully accompanied advances of biological and ecological sciences, becoming more and more fully integrated into disciplines closely related to mining, such as the building design and construction fields. Materials sustainability certification systems have been in rapid development, particularly for forest products (e.g., FSC, SFI) and for buildings, themselves (esp. USGBC).

Throughout recent decades, a worldwide environmental activism movement has propelled, with varying degrees of success and accuracy, political change and public attention to concerns of environment, environmental justice, corporate behavior, world trade, ecological degradation and wildlife losses. More and better-quality information develops on these issues every day. Recognition has become pervasive that humans must redesign their interactions with the earth and with each other to become 'sustainable.'

Mining is not alone among industries or communities, nor can it allow itself to be isolated in any sense. Former Saudi Arabian Oil Minister and OPEC spokesman Sheik Ahmed Zaki Yamani famously said, "The Stone Age came to an end not for a lack of stones, and the oil age will end but not for a lack of oil." (quoted in London *Daily Telegraph*, www.Telegraph.co.uk, June 25, 2000). This approaching end may be true for the oil-for-energy industry, though, for oil and for coal, one can imagine these forms of carbon becoming the primary basis for other materials made of carbon molecules --- plastics, carbon composites, etc. --- instead of being burned for energy. For minerals and mining, however, the "stone age" seems destined to remain, insofar as mining is able to learn to operate within the constraints of the world, its communities and its environment. For both mining and the carbon fuels industries, however, a "soft landing" approaching sustainability can only be accomplished by rapid, decisive action.

International Sustainable Development Efforts

For decades, public policy, scientific and environmental discourse and literature have become so filled with 'sustainability' debates as to make the subject inescapable, if little more comprehensible. The very meaning of the word and its associated phrases, especially 'sustainable development,' has become obscured by proliferation of uses at least as great as the number of users. Many trivialize the term by narrow, metaphoric or outright false 'greenwashing' claims. A brief, critical review of the most useful work is necessary in order to advance our discussion of sustainable mining.

Brundtland Commisssion: The most famous definition, that of the World Commission on the Environment and Development, usually known as the "Brundtland Commission," characterized sustainable development as:

> "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

We contend that this definition is unacceptably anthropocentric (i.e., human-centered) unless other key Brundtland Commission formulations, seldom quoted, are included to make the definition complete:

> "Sustainable global development requires that those who are more affluent adopt lifestyles within the planet's ecological means."

And:

> "Sustainable development can only be pursued if population size and growth are in harmony with the changing productive potential of the ecosystem."

It was clearly the intent of the Brundtland Commission that these formulations be used in concert, not in selective isolation, which has led to mischaracterization of the Commission's definition of sustainability.

UNEP Stockholm Conference and Rio Declaration on Environment and Development: In 1992 at the United Nations Conference on Environment and Development, 27 'Principles' from the 1972 Stockholm UN Conference on the Human Environment were adopted to guide sustainable development. (The "Rio Declaration" is available at http://www.unep.org/Documents/Default.asp?DocumentID=78&ArticleID=1163.) Although these principles are numerous, they may fairly be reduced to emphases on: interdependence and indivisibility of peace, development and environmental protection; human health, welfare, equality and economic equity; harmony with nature and unconditionally protected environment and ecosystems, all subject to the 'precautionary principle;' adequate environmental laws and mechanisms of universal citizen participation in regulatory processes; constraint of unsustainable demographic and economic policies; and avoidance of war. There is likely to be little disagreement that these principles, drafted largely for conduct of nations among nations, are indeed necessary and worthwhile. It remains obvious, however, that they are not intended as practical guides for companies or individuals seeking sustainability.

UN 'Environmental Management of Industrial Estates': A 1997 report prepared by the UN Environment Programme Industry and Environment office addressed "industrial estates" and their imperatives, putting forth "key principles and approaches":

- The precautionary principle
- Integration
- Environmental planning
- Ecological design
- Total quality management
- Cleaner production and resource recovery
- Industrial ecology.

Intended for application in industrial parks, districts, zones, clusters, processing zones, development zones, and other types of intensive business, office, science, research, high-tech and eco-industrial parks, the "Industrial Estates" guidelines were the first to make a case for unified management approaches, concepts and minimum standards. A very useful set of 'Worksheets' are provided, along with brief cases describing possible 'eco-efficiencies' in industrial estates. Like the Rio Declaration and other UNEP documents, however, there are no requirements or specific formulations provided for a given industrial facility to approach sustainability. This work is, nonetheless, a significant contribution toward action.

World Bank, International Monetary Fund, Asian Development Bank, Latin American-Caribbean Initiative, Inter-American Development Bank, USAID and Others: Much of the specific work on sustainable development topics, including some on mining and a great deal on energy, agriculture, transportation and industrial technologies, has been done through special projects of these enormously important institutions and organizations. Technology transfer from industrialized nations to developing countries and supporting pilot project investment are critical priorities.

Foundations and NGOs: Despite painful losses in economic downturns of the 20th-21st Century transition, private foundations remain among the most important players in conceptualizing the meaning of sustainable development, particularly in the developing world.

Other Recent Sustainable Development Work: A great deal of publishing has occurred around the general 'sustainability' topic, most relevantly directed at sustainable businesses and business opportunities. Most well known have been:

- Hawken, Lovins and Lovins, *Natural Capitalism*;
- Hawken, *The Ecology of Commerce*;
- Daily and Ellison, *The New Economy of Nature*;
- Robert, *The Natural Step;* and
- Wackernagle, *Our Ecological Footprint*;
- Storm, *The Restoration Economy*;
- McDonough and Braungart, *Cradle to Cradle.*

Less well known, but of equal or greater depth and specificity are:

- Romm, *Cool Companies*;
- Nattrass and Altomare, *The Natural Step for Business*;
- Lyle, *Regenerative Design for Sustainable Development*;
- UNEP Working Group on Sustainable Product Development
- Organisation for Economic Cooperation and Development (OECD)
- Consortium on Green Design and Manufacturing (CGDM);
- ASTM and ISO, numerous standards for sustainable systems, products and materials

And, perhaps most useful, a veritable explosion from a single writer, Chris Maser:

- Maser, *Sustainable Community Development*;
- Maser, *Ecological Diversity in Sustainable Development*;
- Maser and Silberstein, *Land-Use Planning for Sustainable Development*;
- Maser, Beaton and Smith, *Setting the Stage for Sustainability, a Citizen's Handbook*;
- Maser and Beaton, *Reuniting Economy and Ecology in Sustainable Development.*

In the first, Maser elaborates the ten "elements" of an ecologically-centered and, simultaneously, community-centered vision of sustainable development:

- "First Element: Understanding and accepting the Inviolate Physical Principles Governing Nature's Dynamics
- "Second Element: Understanding and Accepting That We Do Not and Cannot Manage Nature
- "Third Element: Understanding and Accepting That We Make an Ecosystem More Fragile When We Alter It
- "Fourth Element: Understanding and Accepting That We Must Reinvest in Living Systems Even as We Reinvest in Business
- "Fifth Element: Understanding and Accepting That Only a Unified Systemic World View Is a Sustainable World View
- "Sixth Element: Accepting Our Ignorance and Trusting Our Intuition, While Doubting Our Knowledge
- "Seventh Element: Specifying What Is to Be Sustained
- "Eighth Element: Understanding and Accepting That Sustainability Is a Continual Process, Not a Fixed End Point
- "Ninth Element: Understanding, Accepting, and Being Accountable for Intergenerational Equity
- "Tenth Element: Understanding, Accepting and Being Accountable for Ecological Limitations to Land Ownership and the Rights of Private Property."

Maser contends that, "… sustainable development is an ongoing, locally directed community process, not a fixed end point. Sustainable community development integrates human values based on the intellect and the intuitive, the material and the spiritual. As a shared vision of social/environmental sustainability within a fluid system devoid of quick fixes, sustainable community development is integrated learning, communication, and work for the benefit of both the present and the future, because today's choices become tomorrow's consequences." He asserts, further, that, "…economics without humility is every bit as dangerous as science without morality." "To achieve the balance of energy necessary to maintain the sustainability of ecosystems, we must focus our questions, both social and scientific, toward understanding the physical/biological governance of those systems. Then we must find the moral courage and political will to direct our personal and collective energy toward living within the constraints defined by ecosystem sustainability and not by political/economic desires." (Maser, *Sustainable Community Development, Principles and Concepts).*

In aggregate, these bodies of thought, with some important qualifications and refinements, establish an overarching vision, within which we may begin to conceptualize a mining industry that may approach sustainability --- indeed, *must* approach sustainability if it is to sustain itself financially and economically.

Sustainability Characterized: Sustainability is not just a technological or economic/financial problem, though it certainly must integrate these considerations into its constantly-adapting responses. Concepts of sustainability, sustainable development or specific 'sustainable' activities, such as mining, must commence from recognition that sustainability is part myth, part vision, and part goal, or elusive objective. Sustainability is not a badge, not an award, not a plaque by the door. It is neither a status bestowed nor a claim made legitimately, nor is it an endpoint reached by the application of prescriptions, proscriptions, or both.

As much art as science, as much ethics as regulatory oversight, as much an alternation between restraint and exertion as economic consistency, sustainability is a condition we can say a system has reached only after it has done so. Given the thermodynamics of human existence, which are more conducive to entropy than to creation or natural restoration, sustainability may be seen as an environmental asymptote, never reached, but only approached, even if we strive as rigorously as we are able. Sustainability is, however, by no means as mechanistic as this. In fact, discussion of sustainability concepts requires establishment of some sort of philosophical and ethical framework, precisely because this is the part that is most lacking, due to targeted suspension by governments, corporations and individuals in positions of power over industries most in need of revectoring course toward sustainability. The considerable effort that will be required to approach a sustainable condition is justified by the chance to maintain stable environmental, ecological, social and economic conditions, relatively free of risk that systems will fail or collapse.

Environmental Risk and Pascal's Wager, Global Variation: Businesses frequently speak of need for 'certainty,' for minimization of risk. If 17th Century French philosopher-mathematician Blaise Pascal were alive today to consider our current gamble with global warming and other planetary-scale and regional environmental changes that may be attributable to humans, he might propose an environmental, ecological and socio-economic sustainability counterpart to his famous 'Pascal's Wager.' This 'Wager' a theological reasoning, was meant to argue for the existence of a Christian God. Pascal, fascinated by gambling and gamblers, predicated his argument for belief in the existence of God thusly: If we believe in God, and live and behave accordingly, but are wrong (i.e., it turns out that there is no God, no afterlife), then what we will have lost is transitory, of only passing importance. If, however, we *disbelieve* in God and live and behave accordingly, and are wrong (God and hell exist), then what we will have lost is eternal.

We postulate here an environmental wager, by analogy to that of Pascal, appealing both to enlightened self-interest and to sense of community, including all levels from family to nation to globe. Recognizing this environmental 'wager' is fundamental to the individual and organizational restraint necessary to live and operate within ecological constraints.

Applying Pascal's Wager to the looming environmental 'perfect waves' of pollution, resource depletion, socio-economic instability and to the conspicuous threat of global climate change, the wager consists of the following: If we wager that natural and environmental systems are of utmost importance to human individuals and communities and also have intrinsic value, we live and work accordingly, and are *wrong* (i.e., global warming and other possible trends do not come to fruition), then we will have sacrificed little. Indeed, we may even have arrived at efficiencies such as for energy systems that not only impose less cost, but that accrue wealth. If, however, we wager that natural systems such as global climate are insignificant and not subject to human influences, we live and work accordingly, and are *wrong* (i.e., global warming or other possible catastrophic trends occur), then what we will have lost will be functionally *geological* in duration and disruptive of human quality of life, as well as of ecological systems, in the extreme. The carrying capacity of Earth and most human economies will be disrupted for an interval longer than the term of civilized history.

Sustainability is, therefore, one way to measure the risk of our wagers, environmental, ecological, economic and social, for ourselves, our communities, contextual ecosystems, and our environment at all scales. The wagers of industrial Western societies have been perilous, by ecological measures. Humans, after all, are as dependent on ecosystems as any other organism; perhaps moreso.

The archeological, paleontological and stratigraphic record tell us that earth's habitability is episodic, characterized by favorable periods lasting thousands or tens of thousands of years over parts of the planet, at minimum, and much longer at some locations. We live still and forever in this paleo-ecological context, availing ourselves of the hospitable intervals, fitting our notions of 'sustainability' into such a naturally hostile, but utterly unique planet. "Earth First" makes an amusing bumpersticker, but the actual earth is the only one we know.

Sustainability Specific to Place and Time: Any sustainability vision, goal or set of objectives with a chance to succeed should be specific to place and time, though long-term of vision and globally aware. It follows that this sustainability vision should be constantly reviewed, monitored, adapted and revised to accommodate new information, changing science and public policy, changing demographics, changing economic conditions and markets, and organizational and community directions. For most of us, sustainability did not mean the same thing on 9-12-01 as it meant on 9-10-01, nor could it have retained validity, if it existed as a concept during those days, in locations such as Afghanistan or Lower Manhattan. Conditions are constantly changing, sometimes precipitously, but usually so gradually that many major changes escape our attention. Nonetheless, 'place' must be understood thoroughly in historical dimensions, and must be projected into a future as distant as possible, addressing alternative future scenarios.

Sustainability is High Expectations. An adequately holistic approach to sustainability is here predicated on the following expectations of what would exist were we to approach sustainability. :

- Enduring, relatively stable ecological systems, measured by biodiversity, wildlife and human 'carrying capacities' that these ecosystems support, fully considering most vulnerable subsystem habitat elements at appropriate scales (e.g., local clean water, global climate stability);
- Enduring local, regional and global human communities, essentially stable in consumption of land and other fixed resources, sharing with nature, reliant on energy, water and materials from renewable sources, precautionary in environmental management policies, and restorative in both policies and investments, seeking always to correct past damages;
- Enduring economic systems and system members, adaptable and responsive to changing markets and conditions, with the assistance of cooperating businesses, organizations and governments, and exercising appropriate technologies at appropriate scales to achieve greatest efficiencies, converting problems into opportunities wherever and whenever possible.

Appropriate Solutions at Appropriate Scales: Both problems and opportunities occur at large scale, small scale and everything in between. This is true of responses, as well. It is inherent in our business and governance culture, however, to strongly prefer 'big box' responses to every challenge we face. Need tax revenues? Recruit WalMart. Need to clean up a contaminated site? Dig the entire site up and put it over there. We see the world much too simply and much too narrowly, whether out of laziness, avarice or culturally-accepted norms. Too much attention is directed at 'the bottom line,' we often hear, and not enough --- if any --- at the large-scale phenomena around us, even trends showing signs of approaching crises. Challenges or needs perceived to be 'small' are generally neglected, unless there is 'PR value' or marketing advantage inherent in response.

Throughout the business world, a much more finely-attuned *process* of response needs to be developed if businesses and governments, including mining industries, are to approach sustainability. The capacity to conduct this *process* must be acquired, as a critical prerequisite, and maintained throughout the life of a business or organization. This 'capacity' means the organizational intelligence, the organizational structure, and the individual ability to perceive, assess and respond to challenges and opportunities, as well as to strategic, normative change, in which the norm *is* change. Understanding the world around us at concentric circles of scale is just the beginning. We should be able to respond to challenges and opportunities with integrated solutions, sometimes small and cooperative in nature, sometimes with large-scale awareness integrated into the picture, and occasionally with a single, large, pre-integrated 'turnkey' solution (the result of someone else's visionary forethought) --- this is a key capacity. To bypass small solutions because they are small, however complex their integration may appear, is fatal to sustainability approach.

Disproportionality of management attention, investment, policy, regulation, community energies, NGO analysis, activism, or any other variable in the complex system that must make up a whole, functioning, *sustainable system* will render the whole ineffective, unsustainable. Balance is essential to sustainable responsiveness. It is unfortunately typical of industry to hold a narrow view of broad phenomena, often calling it "focus" or "core business." Mines "put rocks in boxes," for example. The age of getting away with hyper-selective effort may be approaching an end, in a world in which complex interrelationships are increasingly inescapable. This is not to say that we can't specialize. Indeed, we must. But we must also cooperate, and enter into collaborative planning and management. Maser's "Fifth Element," that a "only a unified systemic world view is a sustainable world view," may fly in the face of business school wisdom about narrowly defined targets, business focus, 'sticking to your knitting,' and 'core business' concerns, but it is an incontrovertible key to approaching sustainability.

As we will see in examination of a conspicuous case, narrowness and selectivity of attention is characteristic of environmental management, as well as the regulatory regime that supports industry, mining being no exception. Narrowness is an attribute beyond which we must seek to grow.

Mining, Environment, Community and Planet: The Question of Sustainable Mining

The Mining Experience. Margins approached in any economic activity produce familiar phenomena, most relevantly including rising costs, rising values, increased competition for markets and lands and from substitute products, and increased resistance from communities. Population growth, specifically of urbanizing areas worldwide, has put mining industries, especially metals-producing mining, smelting and refining, into increasingly abrupt confrontation with environmental, social and community resistance. In many cases, mines have preceded communities in their developmental history, contributing to regional economies and fueling the very population growth that ultimately comes into conflict with encroaching communities.

Degraded air quality, surface water resource impairment, ground water contamination, land-use disruption, deforestation and devegetation, physical public safety hazards, and soils acidification/toxification are all effects familiar to those immersed in mining history. The number and extent are almost incalculable. (As a reflection, there are more than 20,000 abandoned mines in the state of Utah, alone.) In some cases, these and other effects may have been caused by ill-considered attempts to correct mining-generated problems, the cure being worse than the initial malady. In others, accumulating mine waste discharges, whether deliberate or inadvertent, have become ecological threats, creating marginal constraints where none may have existed before. New problems have emerged that are global in scale, such as climate change, consequences of energy use, probably assuming top corrective priority for generations to come. Size matters in contaminated and impaired environments, often determining the scale and complexity of appropriate, restorative or compensatory responses.

All over the world, mining companies are coming to grips with concern and resistance, despite the obvious necessity of metals and non-metal mine products, and despite the critical contributions mining has made for all human history, and continues to make, to economies local, regional, national and global. Reconciliation of economies with environments, communities with industries, precedents with legacies, has consumed sufficient ink and paper to constitute almost an industry in and of itself. It is nonetheless undeniable, however, that mining in the American West and in many other places in the world is at a crossroads, a nexus at which patterns, paradigms and corollary practices will be established to carry minerals exploitation and development into at least the next century, if not beyond.

MMSD: Major work toward 'sustainable mining' has occurred in recent years in the form of important collaborative processes, international conferences, extensive compilations and monographs, and the beginnings of individual company plans. Among these, the 'MMSD Project' is by far the most conspicuous and among the most significant. Sponsored primarily by international mining giants, development agencies and institutions specializing in mining, and guided by the World Business Council for Sustainable Development and the International Institute for Environment and Development, the "Mining, Metals and Sustainable Development" (MMSD) initiative began in 1998 and ended in 2002 (MMSD-IIED publications available at http://www.iied.org/mmsd/). Initiated by nine major mining companies and conducted over a period of less than four years, the landmark MMSD process was one of the most extensive and intensive such efforts in the history of any industrial sector. Constructive, useful systems were formulated to guide mine- or company-specific objectives, principles and checklists, working toward sustainable mineral resources, secure 'social license to operate,' and sustainable contextual environments, economies and communities.

Important products came from MMSD:

- *Mining for the Future: Main Report* addressed a set of primary concerns of the mining industry, large volume waste, mine closure and abandoned mines. 'Best Practice' is suggested "as a process, rather than as a series of design elements." This echoes approaches employed in many other industries, conspicuously agricultural and forestry industries that seek to redefine themselves for approaching sustainability, employing 'best management practices' (BMPs). "Sustainable development drivers" are outlined: environmental, socio-economic, corporate and regulatory. 'Environmental considerations' are explored in terms of waste disposal. Through appendices, the report introduces 'working papers' on large volume waste, closure, abandoned mines and other policy issues.
- *Sustainability Indicators and Sustainability Performance Management* establishes methods of measurement of sustainability. The report "…argues that tailor made approaches to developing indicators, that address specific stakeholder concerns and that inform mainstream corporate strategy and support companies' future approaches to managing sustainable development issues, are more likely to contribute to sound investment decision processes than approaches which prioritise reporting against generic 'off the shelf' indicators. Notwithstanding, it is suggested that the latter can inform the former; and, that there are merits to developing combined 'top-down' – 'expert derived' and 'bottom up' – 'stakeholder scoped' approaches to sustainability performance management." (*Sustainability Indicators…*, Warhurst, MMSD, p. 3)
- *Finding the Way Forward: how could voluntary action move mining towards sustainable development?* After an updated summary of 'pressures and drivers,' this report explores voluntary initiatives and the prospect of third-party certification, an approach far into process in the forest-products industry, with varying degrees of success. A 2001 workshop on "Voluntary Initiatives for the Mineral Sector" drew the following conclusions useful to this discussion:
  - "Objectives should go beyond legal requirements.
  - Flexibility in application is needed.
  - Consistent principles are important.
  - The scale of application should be appropriate.
  - Voluntary initiatives should complement other instruments.
  - Voluntary third-party verification should be used." (*Finding the Way Forward*, MMSD, Box 3.1, p. 22)
- *Finding Common Ground: Indigenous Peoples and Their Association with the Mining Sector*
- *Room to Manoeuvre? Mining, biodiversity and protected areas*
- *Artisanal and Small-scale Mining: Challenges and Opportunities*
- *Breaking New Ground: Mining, Minerals and Sustainable Development*, the Final Report of MMSD. This report is one of the most important ever to be produced by and for the mining industry. Through a process led by Richard Sandbrook, *Breaking New Ground* provides a uniquely complete and balanced overview of what is required for mining to become sustainable. Like *Mining for the Future*, the MMSD Final Report emphasizes "Best Practice," and its "local solutions":

  > "A frequent response to questions about what constitutes 'best practice' is that 'it all depends'. Best practice should be defined by decentralized and iterative processes, not by a fixed set of parameters that can be read out of a manual." (*Breaking New Ground*, Executive Summary, p. xxiii)

  Beginning with review of sustainable development history, concepts and principles, the report contributes enormously to the discussion of process to get to sustainability:

  > "The on-going theoretical debates about sustainable development should not obscure its usefulness as a decision-making tool. Perhaps one way of understanding how to use the idea of 'capital' [referring to concepts of 'natural capital'] is to divide decisions into three groups [bracketed comments are the present author's]:
  >
  > - *'Win-win-win' decisions* – Some decisions advance all the goals identified by sustainable development simultaneously: they improve material well-being more equitably, enhance the environment, strengthen our ability to manage problems, and pass on enhanced stocks of capital to future generations. These are obvious 'wins' and should be acted upon.

- *'Trade-off'decisions* – Other decisions will result in both gains and losses. If the gains are great enough and the losers can be compensated [assuming that they are people], the decision should be to proceed. This is the zone of trade-offs and requires an agreed mechanism for reaching a decision.
- *'No-go' decisions* – A final group of decisions may go past some widely accepted limit, such as destroying critical natural capital or transgressing fundamental human rights. If these conditions hold, the decision should be to not proceed." (*Breaking New Ground*, p. 22)

This conceptual clarity and many other contributions of *Breaking New Ground* to the literature of sustainable mining will mark its place. There is constructive, double-edged frankness, also:

> "There are also financial costs associated with moving towards sustainable development. In some cases, these costs may outweigh the benefits of improvements. Though this report talks of minimizing impacts, in economic terms the aim is to reduce the impacts to the point where the additional costs of reducing these impacts would outweigh the additional benefits. Moreover, the costs of reaching the goals of sustainable development have to be apportioned in a way that ensures that economies remain sufficiently viable to meet the needs of humankind for development and for various products and services – which in turn implies that the prices paid for products must reflect the true costs of providing them. Some change will be achieved by win-win efficiency gains (such as a reduction in energy use), but much more will involve internalizing costs that have been outside the market system thus far." (*Breaking New Ground*, p. 22.)

The democratic bases of MMSD's envisioned process are most visible in the report's observations about 'multistakeholder processes:

- "A broad-based, inclusive process of initiation is fundamental to the success of the effort.
- The time frame must take into account the differing capacities of participants as well as the need for a timely outcome.
- No one group should own access to the process or its follow-up.
- A group that is trusted for its diversity and its insights must be given primary responsibility for steering the process on behalf of all others.
- No process should override the importance of local endowments (cultural, environmental, and economic); thus decentralization should be the guiding rule.
- The initial scope must be agreed to by all, and be subject to revision as the dialogue unfolds.
- The process cannot succeed if any one stakeholder attempts prematurely to claim the high ground in public, or works in private to circumvent due process.
- The rules of evidence are crucial – everyone needs to work to the same standards of rigour, honesty, and transparency.
- Any financial resources applied should not affect the relationship; at the same time, appropriate responsibilities for follow-up have to be recognized." (*Breaking New Ground*, MMSD Final Report, Executive Summary Box ES-2, p. xv)

- *The Life Cycle of Copper, Its Co-Products and By-Products,* Ayres, Ayres and Rade, (MMSD 2002) is the most thorough exploration of a single metals product group done applying life-cycle assessment (LCA) methodologies. Ayres and Ayres are also among the world's leading exponents of industrial ecology, specializing in materials life cycle analysis and flows.

GMI and ICMM: The "Global Mining Initiative" (GMI), an organization formed by twenty-eight of the world's largest mining, metals and minerals companies and headquartered at Rio Tinto's London location, was established in the 1990s. MMSD was sponsored by many of the GMI participants. Since the 2002 completion of MMSD, GMI has initiated follow-up through the "International Council on Mining & Metals" (ICMM). As reported in MMSD's *Finding the Way Forward,* ICMM "…has taken up the task of developing the findings of MMSD into concrete actions through its member companies. An ICMM Declaration on Sustainable Development was launched at the Global Mining Initiative conference in Toronto in May 2002. The ICMM 'Toronto Declaration' stated the following (bold face type ICMM's):

"ICMM will:

- Expand the current **ICMM Sustainable Development Charter** to include appropriate areas recommended in the MMSD Report.
- Develop best-practice protocols that **encourage third-party verification and public reporting**.
- Engage in **constructive dialogue** with key consituencies.
- Assist Members in **understanding the concepts** and application of sustainable development.
- Together with the World Bank and others, seek to enhance effective **community development management tools** and systems.
- Promote the concept of **integrated materials management** throughout the minerals value chain wherever relevant.
- Promote sound **science-based regulatory and material-choice decisions** that encourage market access and the safe use, reuse and recycling of metals and minerals.
- Create **an emergency response regional register** for the global mining, metals and minerals industry.
- In partnership with IUCN-The World Conservation Union and others, seek to resolve the questions associated with **protected areas and mining**." (*Finding the Way Forward*, MMSD, Box 1.2, p. 6)

UNEP MRF: The United Nations Environment Programme 'Mineral Resources Forum' (MRF) describes itself:

> "The Mineral Resources Forum (MRF) is an information resource for issues related to mining, minerals, metals and sustainable development. It seeks to engage a diverse set of users from governments, mining, mineral and metal companies and other concerned civil society institutions, and to promote an integrated, inter-disciplinary approach to mineral issues and policies. The MRF is designed to accommodate a broad and growing range of technical and socio-economic issues that arise during the life cycle of mineral resources, i.e. as resources are: discovered and explored; exploited, transformed and traded; and finally consumed, disposed of, or recycled." (MRF website, http://www.natural-resources.org/minerals/aboutf.htm)

MRF has actively promoted information exchange among Forum participants, and publishes occasional papers of relevance to the industry. These papers are generally available in digital format on the MRF Library website (http://www.mineralresourcesforum.org/library/index.htm). Often topically specialized, they range from training and technology screening to environmental problem case studies, environmental literacy workshops and discussions of human rights in resource development.

IDRC: The International Development Research Centre, with the World Bank, sponsored and published a notable work, *Large Mines and the Community: Socioeconomic and Environmental Effects in Latin America, Canada and Spain*, edited by McMahon and Remy. Utilizing comparative case studies, six distinct areas are analyzed for their reflections on sustainability of mining operations and surrounding communities and their economies.

Industrial Ecology and Sustainable Mining

The concept of industrial ecology (IE) includes both the metaphor and the necessity of ecological analysis, focusing on 'place' in a sense larger than immediate site. IE offers strategies for converting present and previous neglected resources into economically viable materials and energy resources, all contributing to the possibility of enduring businesses and employment. These forms of economic prosperity, in turn, may build values and capacities for further economic growth. Where land holdings associated with mining can be converted to non-mining urban developments, the economic value level of the lands proximate to communities that are prospering by IE practices stands to be higher, more long-lasting and more capable of surviving economic shocks associated with a given commodity market than is a less diversified, less self-aware community. Diversity in biological systems is a key survival attribute. Diversity in 'industrial ecosystems,' similarly, is key to community prosperity, survival and values.

Supplemented, clarified and extended by the rapidly-developing discipline of 'industrial ecology' (IE), the recent MMSD, UNEP/MRF and ICMM visioning of sustainable mining may be forged into a *practically* constructive approach to sustainable mining in sustainable communities, economies and environments, at appropriate scales.

Making sustainability pay for everyone, including mining ventures, surrounding communities and the environment as a whole, is the problem at hand. Industrial ecology provides a generalized, adaptable methodology, a set of practical business approaches to these enormously complex challenges, without losing sight of ecological responsibilities. By IE application, practitioners can integrate community-based notions of sustainability with economic development oriented toward high-efficiency technologies, co-located industrial/business clusters, collaborative commitments to resource optimization, and business development for the community as a whole, again at all scales.

IE Origins and Development: Industrial ecology is a tool of relatively recent origin and of rapidly-growing popularity. Ernie Lowe, author of a number of industrial ecology texts, characterizes IE as an "…interdisciplinary framework for designing and operating industrial systems as living systems that are interdependent with natural systems." (Indigo Development website, www.indigodev.com).

The analogy to natural ecosystems is loose, not to be taken literally beyond that of a model. It asserts that "models of non-human biological systems and their interactions in nature are instructive for industrial systems that we design and operate…. An overarching goal of IE is the establishment of an industrial system that cycles virtually all of the materials it uses and releases a minimal amount of waste to the environment." (*Industrial Ecology: Some Directions for Research*, pre-publication draft, Rockefeller U.). Because of the proprietary nature of companies, we are restricted here to the part of the industrial system for which we can obtain information.

Energy, land, water, jobs and ecosystems are the most likely categories of attention on mine sites. Visualizing ecosystems and biological organisms, as IE guides us to do, promotes recognition in mining industries (as elsewhere) of metabolism, material and energy flows, waste utilization by other 'organisms' (business entities), and symbiotic relationships among subsystems --- and even 'predatory' relationships that may exist. Flows are as familiar to industry as to biological and ecological sciences, but these flows are usually seen almost strictly in resource economic terms, only as materials, energy, costs and cash flows.

Founded in the rising disciplines of ecology and biogeochemistry, drawing on paleo-ecology and the 'basic' earth sciences, mining industrial ecology must also draw upon anthropology, philosophy and ethics. Integrating these ways of thinking into sustainable mining developed by the authorities here reviewed affords a legitimate chance of achieving 'whole mine – whole community – whole planet' sustainability. Fundamental principles are needed, however, to add to the repertory. These 'life-cycle analysis' fundamentals must be put 'on the table' in order to establish the necessity for some responsible methodology, whether IE or another approach, if sustainable mining is to be the goal.

- **Mining wastes and environmental contaminants** are usually the result of incomplete cycles, often of incomplete or poorly chosen biogeochemical, physical or process cycles. Acid mine drainage, huge accumulations of mine waste, and massive releases of carbon to increase climate change probabilities are examples. Fields of scientific awareness necessary for approach to sustainable mining must, therefore, include biogeochemistry and global biogeochemical cycles (ref. Schlesinger's *Biogeochemistry: An Analysis of Global Change, and the* work of Vaclav Smil, *Cycles of Life: Civilization and the Biosphere,* and *Carbon-Nitrogen-Sulfur: Human Interference in Grand Biospheric Cycles.)* Mining, and industries in general, must accept responsibility for creation of underutilized byproducts.
- **'Historic' wastes** or past accumulations of mining wastes must still be addressed in order to restore environmental stability. This follows from acceptance of responsibility for byproducts and incomplete cycles. Past mining waste constitutes an environmental debt; therefore, dealing with it must not be rewarded as a 'voluntary initiative' even though our often weak environmental laws may not require corrective action (e.g., 'grandfathered' waste rock dumps, or acidic/metals-laden ground water emerging years after mines cease pumping.)
- **'Restoration'** must not be viewed as literal replication of what preceded mining, but rather the implementation of what is necessary for prevention of further environmental releases or public health endangerment. Restoration , consequently, pursues the highest-and-best alternative that benefits ecosystems, community or planet, preferably all.
- **Resolution** of one mining contamination occurrence must not jeopardize another ecosystem or habitat in the course of remediating the first.
- **Renewable resource development**, given the universal threat of global warming, must assume very high 'trade-off' value, where 'win-win-win' steps are not possible (*Breaking New Ground).*
- **'Embodied energy'** is the energy required to extract, process, manufacture, and assemble products for consumers, including the typically-multiple transportation events required, the operation and maintenance energy during use, and the end-of-cycle energy to reuse, disassemble, recycle or dispose of the material. Embodied energy is in every product of mining, including finished commodity products *and the waste byproducts* of mining and minerals processing. Tailings, waste rock, process water, contaminated ground water and soils --- all contain embodied energy, which is wasted if these byproducts are not utilized.
- **Wildlife and humans *are****;* they exist, and have as much right to exist as any other being, including the managers and operators of mining companies, government environmental regulators, employees, and community members. 'Existence precedes essence,' Sartre maintained; life is more important than values. This 'eco-existential' point is recognition of fact, not a belief or a religion.

- **‘Embodied death’** is a harsh-sounding concept postulated to recognize that much of what industry does kills living beings in nature, and sometimes people in communities. Pollution badly managed, habitats altered, survival essentials removed, any of these can kill. Once this killing is accepted by decision-makers, where is the line drawn? Impacts must be recognized, even if they occur at remote locations, recognition that is more likely to be shared as the world becomes pressed toward margins both natural and socio-economic
- **Land-use planning** is inextricably interrelated to planning for sustainable mining. Mining companies have imposed buffers as figurative ‘moats,’ or mechanisms of isolation, when what is appropriate for sustainable mining is community integration and involvement. In instances such as the one we will examine in our case study, the nature of relevant land-use planning is urban, recreational and restorative. This is not the case for very remote locations, but no location can escape ecological, community and global environmental necessities in place-specific configurations. This location-driven planning imperative imposes additional complexity, but also offers enormous opportunity.
- **Co-location** (shared use of sites) is critical to industrial ecology. Co-location must be made possible, however, by striving for *zero-emissions*, if not *zero-discharge* performance standards (light and noise included), and emphasis on public safety, in order to allow other activities, including residences, to locate nearby. Once this threshold is crossed, activities may be clustered that formerly were required by regulation or ordinance to be widely separated. Planning and zoning barriers to co-location must be dealt with through local governmental ordinances and enforcement allowances. Without co-location of mixed functions, it is difficult to establish shared resource flows, such as cooperative energy or materials exchanges in business clusters.
- **Hope** is the ultimate human basis of sustainability, and is also fundamental to every sustainable community, at all concentric circles of scale.

Kalundborg and IE’s Beginnings: Industrial ecology’s most famous ‘poster child,’ illustrating basic IE principles, is that of Kalundborg, Denmark. Without setting out to become anything beyond an efficient cluster of activities, the Kalundborg system was established to utilize byproducts of two major energy producers/suppliers:

- 1,500 MW ASNAES coal-fired electrical power plant
- 4 to 5 million tons/year Statoil petroleum refining complex.

- “The electric power plant sells process steam to the oil refinery, from which it receives fuel gas and cooling water.
- Sulfur removed from the petroleum goes to the Kemira sulfuric acid plant.
- Byproduct heat from the two energy generators is used for district heating of homes and commercial establishments, as well as to heat greenhouses and a fish farming operation.
- Steam from the electrical power plant is used by the $2 billion/year Novo Nordisk pharmaceutical plant, a firm that produces industrial enzymes and 40% of the world’s supply of insulin.
- This plant generates a biological sludge that is used by area farms for fertilizer.
- Calcium sulfate produced as a byproduct of sulfur removal by lime scrubbing from the electrical plant is used by the Gyproc company to make wallboard. The wallboard manufacturer also uses clean-burning gas from the petroleum refinery as fuel.
- Fly ash generated from coal combustion goes into cement and roadbed fill.
- Lake Tisso serves as a fresh water source. Other examples of efficient materials utilization associated with Kalundborg include use of sludge from the plant that treats water and wastes from the fish farm’s processing plant for fertilizer and blending of excess yeast from Novo Nordisk’s insulin production as a supplement to swine feed.” (Manahan, *Industrial Ecology: Environmental Chemistry and Hazardous Wastes*, p. 64.)

Kalundborg developed over decades, beginning in the 1960s, not by premeditated design, but rather in response to recognition of possible mutual benefits. It is the best-documented IE occurrence, but far from the only example. Literally countless examples could be cited of ‘folk’ systems, motivated by common-sense desires for efficiency or waste-avoidance, if not by outright economic desperation. In some cultures, the avoidance of damage to nature and to wildlife is a stricture, a fundamental of the culture’s relationship to nature. Few, if any, of these cultures would recognize the relatively uncaring resource profligacy of the American frontier West.

‘Place’ is at the center of an IE approach to sustainable mining. As many of the works cited previously (Maser, MMSD’s *Breaking New Ground, Finding the Way Forward, and Mining for the Future)* have emphasized, formulaic, generically packaged methods probably won’t work. There has been significant previous work to apply industrial ecology to mining:

- Ayres, Ayres and Rade (*The Life Cycle of Copper, its Co-Products and By-Products*, MMSD). Robert U. Ayres and Leslie W. Ayres also co-authored one of the most important texts of IE, *Industrial Ecology:*

Towards Closing the Materials Cycle, a lengthy work focused on minerals, metals, and other industrial materials, including energy resources.

- Multiple essays in *The Industrial Green Game: Implications for Environmental Design and Management,* published by the National Academy of Engineering. In addition to a very clear synopsis of the Kalundborg example, essays by Frosch, Allenby, Stahel and others are important contributions to IE. An essay by then Kennecott Utah Copper V.P. Preston Chiaro outlines company environmental management.

Kennecott: Case Study for IE-Based, Community-Centered Sustainable Mining

Kennecott Utah Copper is located in the Oquirrh Mountain range, on the west side of the Jordan River Valley, south of the Great Salt Lake (generally referred to as the 'Salt Lake Valley'). The Valley forms the dividing line between the Rocky Mountain physiographic province and the Great Basin province, of which the Oquirrhs are part. Climatically semi-arid, the highest peaks of the Oquirrh range reach 10,000 or more feet above sea level, while the Wasatch to the east reach approximately 12,000. Precipitation shapes much of life's possibilities in this region, with most (85% or more) falling as snow in high elevations. Valleys receive as little as 11 inches per year, while some areas of the Wasatch average nearly 60 inches/annum, and of the Oquirrhs, around 40 inches/annum. The water storage mechanism of high-country snowpack is, in itself, one of the great resources of the region, augmented greatly by typically enormous valley aquifer storage capacity. The Great Salt Lake is, of course, very saline and cannot be used.

Kennecott's mine is perched on the upper east flank of the northern section of the Oquirrh Mountains, a range oriented nearly straight north-south, extending from the Great Salt Lake on the north, southward approximately 32 miles, beyond which a low ridge continues on to connect to the Tintic range, where the historic mining area of Eureka is located.

Kennecott Utah Copper Company, with its huge mine, smelter, refinery and post-mining land use conversion plan, is illustrative of the extent and variety of obligations and opportunities inherent in urban-proximate mine life, presenting a useful case for postulating a regional model of sustainable mining. A mosaic of requited and unrequited sustainability vision, so far, Kennecott occupies a position next to a rapidly-growing urban area that renders the site in a category of its own. As an extreme mine-site type that we might term, "urban-margin," it is also extreme in its illustrative value for problems, opportunities and unresolved dilemmas.

Geographic, Historic, and Demographic Context: Utah's mining scene came to life in the years after the California Gold Rush. Silver and gold began to pour from the canyons of the Wasatch east of the Salt Lake valley, especially around Park City, and from the Tintic range to the southwest. Discovered in the early 1860s, the Bingham metals-mining district developed over the post-Civil War years as a tumultuously enthusiastic beehive of placer and underground operations in the Oquirrh Mountains, which form the Valley's western flank. Silver, lead, zinc and copper were mined from skarn deposits and intrusions into limestone until the turn of the 20th Century, but the known deposits of copper porphyry were left largely untouched because of inability to feasibly process the ore. Concurrently, world copper markets were experiencing a roller-coaster ride, driven increasingly by the budding copper magnates of Butte, Montana, some with Utah financial backing. Porphyry copper was safely in the ground, for the moment.

Daniel Jackling's metallurgical leap at the beginning of the century, however, initiated the mining and processing of porphyry copper, the world's first successful attempt to make mining low-grade copper ores pay off. From this act of genius came Kennecott, the open-pit Bingham Mine, and the episodic consolidation of mining properties in the 'Oquirrhs.' Lands initially held as federal lands, primarily National Forest, were eventually turned over to Kennecott, and the company purchased one after another of the hundreds of claims and active mines in the area. This consolidation continued for at least a half-century on both sides of the range, resulting in the present company holdings of approximately 92,000 acres (approximately 142 sq.mi.), 90% of it in Salt Lake County, from the crest of the Oquirrh range eastward. The Barney's Canyon Gold Mine, immediately north of the Bingham pit, has now been closed, though ore leaching continues. The Bingham Mine, Smelter and Refinery settled down to becoming the nation's second-largest copper mine, producing about 15% of the total, supplemented by 400,000 ounces of gold per year and several million ounces of silver/annum.

Around half of these properties are in the valley or foothills, areas that had become populated with mine and smelter workers in mining's early days. As the company purchased more and more of these lower-elevation lands, they were gradually cleared of habitation, except for the former 'company town' of Copperton at the mouth of Bingham Canyon itself. Thus, a large liability and environmental management 'buffer' was placed between Kennecott operations and the towns and most of the agriculture in urban outskirts. Now, as the Bingham Canyon Mine enters its last few decades of operations, it is one of the largest (if not the largest) of open pit copper mines in the world, and one of the historic leaders in metals production, including copper, gold, silver and molybdenum.

Environmental and Community Context, Problems and Effects:

- **Soils:** Kennecott has expended possibly more effort and resources performing source-control cleanups than any other mine --- in excess of $200 million since 1990. This has dealt relatively thoroughly with contaminated soils, which one would expect to be a consequence of poorly understood and sporadically managed fine-particle suspended and dissolved mining wastes and leach fluids. Tailings, evaporates, sludges and other deposits of fugitive materials in soils were diagnosed and surgically, but almost completely, removed and placed into repositories at several locations.
- **Waste Rock:** From an open pit mine 2.5 miles in diameter and nearly 1/3 mile deep, from which approximately seven billion tons of overburden and ore have been removed (~450,000 tons/day of overburden, at present), it is not surprising that there are approximately five billion tons of waste rock distributed on hillsides and in canyons around the Bingham Canyon Mine, and additional quantities around the Barneys Canyon Gold Mine pits. These waste rock 'dumps' consist of widely varying rock types, with varying sulfide mineral content, depending on what qualified as ore in any given set of market and productivity conditions.
- **Water:** Acidic waters form spontaneously as bacterially-mediated pyrite oxidation occurs in the presence of moisture and oxygen in waste rock dumps. Because most underground mining was in limestone or skarn host rocks from the Lark area or south, there was significant acid neutralization potential, alleviating acid formation from underground mining somewhat. For decades of Kennecott's operations in the copper-bearing porphyry deposits, however, covering more than one-half century, acidic leach water formation from these less neutralizing rock types became extreme. Observing that it carried significant metals, leach water was encouraged and eventually engineered at Kennecott, as at some other contemporary mines, sometimes with enhancement of applied sulfuric acid from processing, to leach metals by design from waste rock.

  This became a legitimate method of dump leaching for copper recovery (ref. Brierly, "Microbiological Mining," *Scientific American,* Aug. 1982 V.247/No.2). Leach water of very low pH/high acidity (as low as pH 2.5, with extremely high mineral acidity from dissolved aluminum, iron, copper and other metals) was created in very great quantities, some captured but some fugitive. Recognizing the resource-recovery potential of leach waters, Kennecott built a cementation (precipitation) plant to exchange scrap iron for copper, located at Copperton. Collection of leach water for conveyance to the Precipitation Plant was haphazard for many years, conveyed through unlined canals to an unlined reservoir. The system was 'upgraded' in the 1960s, and again in the 1980s, but the conveyance canals and the primary reservoir remained unlined, resulting in enormous rates of leach water leakage into the aquifer, reportedly between one million and seven million gallons per day. In the early 1990s, the leach collection system was diverted to allow removal of some 2.5 million cubic yards of acidic tailings and sludge from the reservoir basin to allow competent lining of a new reservoir complex. Concurrently, Kennecott constructed large pipelines to replace poorly-lined canals in the collection system. The improvement culminated in the construction of more than two dozen concrete 'cutoff walls' in critical bedrock drainages, intercepting most, if not all, leach water, and diverting nearly all the flow into the new pipe conveyance system. The scale and severity of ground water contamination prior to these measures, however, may be unprecedented. The bulk of the acid/metals contamination plume and the much more extensive but less toxic, diluted and partially neutralized sulfate plume remain in the ground, the subject of a state Natural Resource Damage (NRD) Claim seeking resolution. The extensive, affected aquifer is the core of the NRD complaint, but proposed remediation threatens to relocate these 'contaminants of concern' to another location that is, from an ecological viewpoint, more troublesome than the contamination's presence in the ground. Selenium and certain other metals in 'South End' ground water is very much the subject of present debate, due to its proposed placement in the Magna Tailings Impoundment or in the Great Salt Lake.

  At Kennecott's 'North End,' near the Arthur-Garfield industrial complex that processed much of the output of the Bingham Mine, questionable disposal of fluids left from electrolytic sludge in precious metals refining released great quantities of selenium to ground water, where it emerged into marshes near the Great Salt Lake. For several years, this Se-rich water has been diluted and pumped to the Lake, subsequent to soils cleanup, in order to pump down selenium in the aquifer. This selenium mass transport may be added to that of the south ground water treatment program when they mix in the Lake.

  Ground water recharge and surface water availability for wildlife have been truncated almost completely on the east Oquirrh flank. Until leach water interception, streams flowed freely, though many of them from Bingham Creek southward were contaminated by mining-generated acidic drainage. During decades of early, relatively crude efforts to intercept leach water, when motivation was for copper recovery, not environmental protection, water made its way into these lower drainages only during high-water episodes or from isolated seeps. For the entire length of the Oquirrh Mountains in recent years, however, Kennecott has intercepted the flow of natural streams, essentially cutting off all ground water recharge. Wells drilled for monitoring and extraction have altered hydrological gradients, further eliminating most seeps. Few fresh water occurrences on the surface that might support wildlife remain.

- **Air:** From mining's earliest days in and around the Oquirrh Mountains, smelting and refining, and in some areas, blowing dust, degraded environments by high sulfur emissions, smoke from coal, and deposition of coal-originated toxins. In the early 1990s, however, Kennecott began construction of one of the largest and most advanced copper smelters in the world, completing startup in the second half of the decade. Air emissions from smelting were cut to a very minor percentage of former numbers, perceptibly changing air quality in the region --- that is, until growth of automobile travel began to overcome these dramatic improvements.

Blowing dust from the original, nine square mile Magna Tailings Impoundment, now abandoned, has emerged as a concern during weather episodes when strong winds from the west or northwest precede storms. Although stringent efforts have been made to cover the surface with vegetation to prevent blowing dust, much work remains. It also remains to be seen whether or not this strategy can be maintained without significant nutrient and/or water inputs, especially in the face of regional impacts of global climate change.

- **Paleontological, Archeological and Historical Remains:** Pleistocene Lake Bonneville formed the pre-archeological, and possibly the early archeological, setting for the Kennecott site's significance. Although a great deal of survey work has been done on archeological sites, some of it unpublished in areas where publication brings risk of vandalism and loss, little paleontological research has been possible because of lack of access.

An exception occurred in the early 1990s, when a Kennecott excavation team digging for construction of one of the leach water cutoff walls exposed bones at a depth of more than fifty feet into apparently previously undisturbed soils. Depth indicated great age, so the remains were reported to archeological authorities as required by law, even on private property. The sample bones first examined showed the site to be a possibly significant Pleistocene or post-Pleistocene zoological catalog, including giant camel and many species of small mammals. Indications are strong that other paleo-environments may have existed along the 'Oquirrh Front,' some of which may remain to reflect very ancient times to science and to community curiosity. Areas along the northern Oquirrhs, especially in Little Valley and the other valley mouths, were at elevations coincident with long episodes of Lake Bonneville's shoreline, and may be conducive to rich vertebrate paleontological environmental conditions.

Human occupation of the area as long ago as 10,000 years may be indicated by remains in caves around the periphery of Lake Bonneville, notably at Danger Cave, near Wendover, NV. Study of the Kennecott site may provide opportunity to access sites less disturbed than elsewhere in the basin, largely due to the site's sequestering from public access. Fremont peoples from approximately one thousand or more years ago are documented to have populated the Jordan River Valley. Excavation for contaminated soils remediation exposed one such site on Bingham Creek, itself. The possibility of other such sites cannot be ruled out, since the ancient, pre-settlement environment may have been attractive to ancient humans, given its biological richness.

- **Vegetation and Habitats:** Any exact catalog of plant-animal associations from pre-settlement times in the Oquirrhs and foothills will probably never be known. Such is the extent of disturbance that few, if any, 'reference' ecological communities remain. For all the decades after settlement of the Salt Lake valley, area forests were cut aggressively for building, mining, industry and fuels, until, on the Oquirrh Mountains, the forests were nearly completely removed. At first, this was largely for mine timbers for the hundreds of underground miles of tunnels, shafts, adits and drifts (a USGS publication from the 1960s suggested that more than 1,000 miles honeycomb the Oquirrhs in the Bingham District, descending as deep as 2,500 feet above sea level), a mining complex that must have consumed many millions of board feet of timbers.

Fuel wood use also contributed to deforestation in years preceding extensive access to coal resources of eastern Utah and Wyoming. Cattle and sheep grazing further denuded many of the high valleys and meadows in the late 19th Century and early 20th. In the 1870s, the West's self-made naturalist and environmental crusader of the Sierra Nevada, John Muir, kept a journal of a hike on a trail near the present site of the Kennecott Smelter, remarking on the variety of flowering plants, but failing to mention forests. Coal burning, however, may have reduced burning of wood as fuel, but it caused widespread air quality degradation, with profound impacts on vegetation.

Intensive early smelting and refining essentially denuded many square miles of the northern Oquirrh Mountains, a condition remaining to a great degree today. To the products of coal burning in the Garfield-Arthur industrial center, reportedly one of the world's largest at the time, were added the highly acidic sulfur-oxide gas emissions of ore processing. These gases killed off soil-retaining lichens and low-lying grasses and forbs, almost completely on the landscape of the northern several square miles of the Oquirrh Mountains. Acidic, phytotoxic air emissions effectively caused topsoil to be removed by erosion over the years. While it is true that forbs and grasses have been recovering since Kennecott's 'Smelter Modernization,' and that rocky remnant soils are less acidic than they were several decades ago, forests and overall vegetation assemblages do not resemble their pre-settlement, pre-mining condition except in isolated pockets, primarily south of the Bingham Mine. A local plant ecologist, in fact, suggests that recovery will mimic the progression one can see in a north-to-south transect through the high-elevation Oquirrhs, but that this process will require hundreds or thousands of years, if unassisted by vigorous restoration planting (personal communication, T. Harrison, Westminster College).

As a consequence of Kennecott's buffer acquisitions, adjacent road-building and town development, one of the most conspicuous effects of mining in the Oquirrhs has been the severing of wildlife migratory pathways for all except large ungulates, the 'charismatic macrofauna' of wildlife ecology. Even the large populations of deer, elk and the top-predator cougar are restricted to the areas within the fences, which are moving rapidly ever uphill. Migratory raptors, including many hawk species and the bald and golden eagles, frequent both farm fields and adjacent open properties on and off Kennecott property. Neotropical songbirds exist in relatively large numbers and variety in some seasons, mostly in the high country. Amphibians, however, such as the long-extirpated Western Spotted Frog, have would have no access to proximate, interconnected waterholes, were they to find themselves on this landscape today. It is a partially-recovered wildlife preserve, constrained by lack of water and winter range, and by the incomplete nature of vegetation recovery. (Ref. *Ecological Risk Assessment Northern Oquirrh Mountains,* KUC 1996; Blanchard 1973, *An Ecologic and Systematic Study of the Birds of the Oquirrh Mountains, Utah.*).

- **Great Salt Lake: The** Great Salt Lake is the terminal basin remnant of ancient Lake Bonneville. Hyper-saline, the lake supports an abbreviated, but extremely productive, food web, culminating in the passage through twice per year of five million or more migratory shorebirds and waterfowl of at least 250 identified species. Several million of these migratory birds, which are protected by international treaty, are found in greater numbers on the Great Salt Lake than at any other site in the world. The Great Salt Lake is now recognized as part of the Western Hemisphere Shorebird Reserve Network (WHSRN), and is generally recognized to be among the world's'great aquatic environments for birds --- though not yet recognized under the voluntary 'Ramsar' Treaty, primarily for lack of application for that status.

  The Lake's biological significance, productivity and vulnerability are, together, the single most conspicuous attribute set of Great Salt Lake ecological geography. The Lake ecological web consists of a remarkably short trophic system, heavily dependent on fresh-to-saline gradients and dynamics as a 'terminal basin.' No fish exist in the lake except in a few fresh water inlets. These rare dynamics of the fresh-to-saline gradient, found in only a few terminal basin lakes in the world, compounded by aerobic-to-anaerobic dynamics in the water column of shallow zones (most of the Lake), create a menu of environments that are the essential engine of productive appeal to migratory birds. Brine shrimp, brine fly larvae and other invertebrates in vast numbers feed on the microbiological wealth of this biogeochemical bonanza. Birds, in turn, thrive on this invertebrate cornucopia. Despite more than a 150 years of human impacts --- pollution discharges, minerals extraction and land use encroachment on lake-margin playas and boundary zones --- the Great Salt Lake has continued to support this enormously significant migratory bird population, a 'flock' shared with all of the Americas, from the Arctic Circle to Patagonia. Great Salt Lake ecosystem vulnerability is becoming manifest in both the tightening of the urban development noose, on the one hand, and on the other, the approach of contaminants of concern, especially bird-jeopardizing selenium, to critical contamination thresholds. Much hinges on efforts underway in the Utah Division of Water Quality to establish ecologically responsible numerical water quality standards for toxic releases to the Lake before it's too late.
- **Energy:** Throughout all but the last few years (less than a decade, depending on the measure), Kennecott has depended on coal for its energy, with some few months of natural gas use mixed in. Kennecott utilizes its own dual-fuel, 175 MW (megawatt) power plant to

serve most of its needs, which average around 200 MW. The Copperton Concentrator uses in excess of 100 MW, and the Mine's demand (electric shovels, primarily) are some significant fraction of that. The electrolytic processes of refining, the tailings cyclones, and demand throughout the sprawling complex, make up the remainder of facility demand. Since the new smelter became fully operational, co-generation ('combined heat and power, or CHP) utilizing waste heat has produced around 25-30 MW. To cover any shortfall of internal power production, power is purchased by long-term contract from 'the grid,' by contract with PacifiCorp, the regional power utility. In effect, Kennecott sells its power to PacifiCorp and buys back the power it needs. Electricity demand is a major part of Kennecott's energy picture, a circumstance not likely to improve while the Pit remains operational, given the extensive pumping that will be required to move ground water through remediation treatment processes at extreme pressures. If the decision is made to convert to underground operation, then mining and concentrating would be dramatically less energy intensive, one assumes from the reduced ore production projected.

Envisioning Kennecott as a Sustainable Mine

How can we draw on the guidelines and principles set out by international agencies addressing sustainability, and, most of all, on the principles and methodologies of the mining industry concensus, itself, represented by MMSD, ICMM, IDSR? Can useful principles be drawn from the extensive independent work on sustainability? What deficiencies in the composite of these approaches warrant remedy by additions? How can review of the Kennecott case shed light on sustainable responses to problems and opportunties at Kennecott and in its community and ecological context?

Visualization of Kennecott Utah Copper as a mine fully integrated into its ecosystem and community at all scales, including that of the entire globe, is dauntingly complex. Recalling and applying key elements of the principles emphasized by international bodies constituted of the major mining companies, including Kennecott's London parent, Rio Tinto, should shed light on what is expected on the international sustainable mining stage. Augmented with principles we have uncovered in other internationally prominent sustainable development thought, and combined with conceptual approaches of industrial ecology, we will now assess the potential for opportunities to sustain the mine, to sustain the post-closure economy around the mine to the benefit of the company and the community, and to sustain contextual and global ecosystems, seeking restoration objectives.

Time is of the Essence; Common Sense is Critical to Responsiveness: Common sense and honesty are extremely important. We have seen that there are far too many methodologies, formal criteria, 'sustainability indicators,' principles and expectations to be applied literally. These are the products of a world disinclined to agree on much of anything. To fight through reconciliation of all these approaches would be tantamount to chaos, and would lose precious time to deal with often time-critical problems and opportunities. Remembering the recommendation put forth by several of the theoreticians of sustainability, which we strongly support --- that 'tailor made' plans, avoiding 'off-the-shelf' approaches, are going to be most effective --- we are shaping an approach that responds to Kennecott's possibilities within the constraints of ecosystem and community, striving to enhance the prospects of company, environment and community, together.

Equipped with the our preceding review of environmental and community context and history; combining the three-part triage classification suggested in *Breaking New Ground* ('win-win-win,' 'trade-off' or 'no-go' decisions); with Chris Maser's 'Ten Elements' of sustainability; with consciousness of ecological vulnerabilities and constraints; and with the creative, entrepreneurial mindset of industrial ecology (economy as natural system, zero-waste as baseline, 'BMPs' to achieve zero waste/zero emissions, industrial metabolism analyzing energy and material flows, niche activities complementing co-located or networked industrial systems to diversify and perpetuate the whole, incubator-assisted business development), we will illuminate priorities for action.

Some conclusions may cast critical light on decisions made so far, without implying blame. We hope, nonetheless, that decisions shown to be less than sustainable might be reconsidered where they either fail to contribute to sustainability or are recognizably negative in their effects. Some conclusions will surely support credit to the company for results, and occasionally for process. At bottom, we seek to candidly and critically assess the sustainability potential of a mining company in a particular place, within a particular community, hoping to shed light on mindset and commitment required at any mining operation at any other particular place/community nexus.

Demographic Context: One factor that shapes Kennecott's potential as no other is the extent and location of its land holdings, in the context of regional demographic trends and the events going on around the area. Utah has grown extremely rapidly, and more consistently rapidly than almost any other urban area in the US. There are more rapidly growing cities for a decade here, a decade there, but for prolonged growth rates, few surpass the cities and towns of the Wasatch Front region. Growth is fueled primarily by births among this, the populace with the highest fertility rate in the nation. Growth in Utah depends little on in-migration or on the boom-and-bust cycles of market-sensitive commodities industries, such as mining. The Wasatch Front has experienced sustained growth of at least 30% per decade; recently, the rate has accelerated.

The Utah Governor's Office of Planning and Budget Office of Demographic and Economic Analysis (GOPB DEA), which provides population data to the official 'metropolitan planning organizations' (MPOs), primarily to provide demographic accuracy to transportation infrastructure planning, has projected growth into the next 50 years according to 13 scenarios, tied to various factors. The median scenarios cluster around a projection of approximately five million people living in the "Wasatch Front/Back" area, where there are presently 1.7 million residents. (Wasatch 'Front/Back' includes the following counties: Salt Lake, Utah, Davis, Weber, Tooele, Summit and Wasatch, the counties clustered around the Great Salt Lake and the populous nearby mountain valleys.) At approximately 85-87%, Utah is either the second most urbanized state in the US, or first, depending on the report. ('Urbanized' means percent of population living in towns larger than 5,000.) Guiding growth toward sustainable land uses, toward integration of adequate, efficient transportation into land use patterns, and toward exercising leadership needed in creating a sustainable regional community, is a role for which Kennecott may be uniquely qualified, and for which Kennecott has the power to develop the capacity. Without question, the larger community has granted Kennecott the benefit of the doubt if the company wishes to assume this leadership role.

Kennecott's Resource Opportunities and Obligations: Low-Hanging Fruit and 'No-go' Constraints

An initial "triage" review of resource opportunities and challenges, beyond the narrow process that is the focus of mining and beneficiation, produces the 'parts' for a toolkit to convert into a sustainable mining system. Through the purview being constructed here, moreover, it is possible to recognize obvious regional problems, trends toward resource or habitat vulnerabilities, and possible solutions to those regional problems. This overview will also tell us when opportunities emerge to address global problems; or it may tell us if and when there are critical ecosystems, communities or resource types of special vulnerability that must be respected, or which may be restored in a concentrated way.

We do not attempt to address the internal workings of Kennecott's mining operations, though we are confident that energy savings, shifts from one electrical energy source to another (fossil fuels to renewables) and improvements of efficiencies across the board can contribute greatly to some of the sustainability objectives outlined here. As in any large industrial facility, management coordination to prevent unfortunate or even damaging errors of project choice is a desirable goal. It must be said, however, that the willingness to experiment that underlies some "mistakes" is a highly desirable attribute for undertaking sustainability programs and projects in the zone around the mine --- the focus of our attention here.

Key Issues and Opportunities at Kennecott: Screening for the most significant needs and likely opportunities reveals the following list:

- ***Global climate change prevention*** – The single most urgent 'macro-scale' need, requiring action from all large energy users, and all who hold opportunities to take action, such as Kennecott and Western mining industries. Renewable energy resources development can spawn clusters of mutually beneficial businesses, associated by efficiencies of cooperative resource management and entrepreneurial development, on the 'eco-industrial park' model (e.g., Kalundborg). This is an imperative, a 'win-win-win'.
- ***Ecosystem protection and restoration*** for habitat values and recreation industry potential –
    - The Great Salt Lake is the most important ecological component of the region, host to a hemispherically critical population of migratory birds in the millions. The Lake is key to the region's biodiversity, along with the area's bioregional transition; it is a critical link in a *system* of habitats for migratory birds. The Lake is endangered by many other forces and trends, some natural and some human-caused. It must not be further endangered by deposition of toxic compounds alien to their habitat needs, even if regulatory and legal boundaries allow such action. This an obvious 'no-go' decision; a responsible international parent of the caliber of Rio Tinto (a primary originator of GMI, MMSD and ICMM) would, one hopes, recognize and remedy this disconnect. If *de facto* neglect *is* chosen, the magnitude of this decision probably could not be balanced by the total of all other potential decisions. 'Sustainability' would be placed firmly out of reach by any reasonable measure.
    - Forests, shrublands and native sagebrush lands of the Oquirrh Mountains need extensive restoration, a process requiring several decades (longer in extensive areas damaged by smelting/refining). Native plants propagation on an unprecedented scale can achieve landscape restoration to fit an urbanizing vision, with climate-appropriate native plant species to conserve water; designed preservation and restoration of open space would help land values to skyrocket. 'Win-win-win.'

- Creation of an integrated trails and recreation plan to meet demand from a growing population, within constraints of continued mining and processing. Tourism and recreation are the region's largest industry, by far; the opportunity could be developed, including viewing of a future sustainable mine. 'Win-win-win'

- ***Mines to match our sustainability challenges: Keep mining*** - Continuation of copper/metals and expanded mineral products for as long as the Mine can be made productive, within sustainability constraints. 'Trade-off' decision of complex nature, but far superior, from public interest point of view, to opening new mines elsewhere (e.g., Centurion in SE Utah), where new capacity to strive for sustainability must be created. Our world does, and will continue to, need these materials, especially from responsible mines. The presence of a sustainably-centered mining company capacity, proportional to the magnitude of challenges and opportunities, is key to bringing about analysis, planning, business incubation, investment and development.

  "Go underground." If this means undertaking the long-considered underground operation to reach the deep ore body, then that is preferable to mine closure, from the viewpoint of a 'whole mine' sustainable development potential. While the economy, as a whole, may no longer depend preponderantly on extractive industries, going underground would be a tradeoff worth the downsides in order to 1) keep Kennecott and Rio Tinto engaged in community investment leadership, and 2) keep in operation some infrastructure elements and organizational capacities that would be necessary, with some redirection, to work toward this larger vision.
- ***Community economic condition*** – Need for sustainable jobs, business opportunities, affordable-efficient housing and access to environmental solutions in the surrounding area, both from sustainable mining and from post-mining use conversions and from restoration activities. Neighboring communities need strategic investment, guidance, and financial assistance to NGOs who will carry parts of the burden. The result will be elevation of standards on Kennecott's property boundaries, producing far higher future land use conversion values. But you have to start now. 'Win-win-win.'
- ***Land use conversion*** – Dramatic potential for leadership and problem-solving, married to lucrative business venture potentials, iteratively, over the next century or more, as "smart towns" are created among interconnected open spaces in a restored landscape. 'Win-win-Tradeoffs' mix of very great magnitude.
- ***Materials recovery*** – Completion of mining's beneficiation process through selective recovery of metals and salts from ground water; use of tailings for high-performance building materials production; and aggregate mining from disturbed lands, avoiding need to mine sand and gravel from greenfields sites elsewhere. 'Win-Tradeoffs' mix.
- ***Risk reduction*** on mine waste dumps where recreation and future land use development may conflict (especially in Butterfield Canyon, and possibly in the Lark-to-Butterfield eastern dumps). 'Win-win-win.'
- Completion of ***ground water control*** instruments in areas not adequately addressed by cutoff system. 'Win-win-win;' failure to do so is a 'No-go' decision.
- Stabilize aquifer contamination and restore it to the greatest extent possible over the long term, devoting water resources required to accomplish this restoration *– but categorically not in a manner that jeopardizes the Great Salt Lake or other critical ecosystems.* 'Tradeoffs' will be necessary.
- ***Classification of clean water***, separating it from contaminated water to prevent mixing and allow beneficial or strategic, designed habitat restoration use.
- ***Highest-and-best use*** determinations of damaged lands, considering trade-offs and large-scale/long-term trends in evaluation. 'Win-win-win.'
- ***Life-long learning*** of sustainable mining vision throughout the community, within post-closure, sustainable development and recreation land use conversion, and atmosphere of entrepreneurial leadership through Industrial Ecology.
- ***Business development incubation, investment, investment catalysis*** is critical to industrial ecological actualization. By analysis of resources not presently fully utilized, and by recruiting of businesses to create complementary industries, together with creation of favorable conditions for their establishment, 'eco-industrial parks' may come into existence to add value to all these under-utilized resources.

Kennecott Resource/Opportunities Inventory: An overview of potential for bringing these potentials and constraints to appropriate actualization helps to support these strategic targets. Each is not stand-alone, but rather, drawn into an integrated whole by complementary efficiencies.

1. Energy. Global climate change *demands* energy and carbon offsets and energy development alternatives. Effects of inaction are inescapable, and promise to be regionally significant, possibly reducing the carrying capacity of the region (ref. Wagner, *Preparing for a Changing Climate: Rocky Mountain/Great Basin Regional Assessment*, USU 2002). Because of the sheer magnitude of the threat and the apparently increasing likelihood of its actual occurrence, climate change renders compensatory energy strategies top priority, with avoidance of major ecosystem degradation.

- *Renewable energy*: Kennecott properties possess reasonably good solar and wind energy development potential, based just on geographic generalities. For some solar energy types, the opportunity is made extraordinary by the possibility of solving ancillary problems by these developments. By virtue of its renewable resources, location near transmission facilities and near urban demand centers, Kennecott could become one of the world's leaders among mine sites in renewable energy development and carbon offsets, including integration into 'spinoff' industrial developments. Multiple thousands of megawatts are possible on areas not subject to future urban development, uses which would appear to transcend all others in importance for these damaged lands.
    - ***Wind*** is most feasible near the mountain ridges and on the high, east waste rock dump plateaus. Some valleys channel west-east air movement into isolated, harvestable resources. In recent years, wind generation has become more efficient, dependable, and less prone to bird mortality and public objection. On this already-disturbed landscape, there can be no insurmountable objection to wind generators, though consideration must be given to their location in bringing forth trails and recreation plans. Human aesthetics have to be subordinate to physical needs of the region and the planet. Wind generation startup is the most rapid of any form of renewable energy generation. A comprehensive wind resource assessment is needed to identify best sites; generation should be commenced at these best sites while additional resource assessment is performed to complete a wind development strategy. Estimated magnitude: 200-400 MW.
    - ***Solar Photovoltaic*** *(PV)* power generation can be very significant, given the vacant areas that receive adequate 'insolation.' Many candidate areas are not good for wind. By covering many of these areas with advanced PV systems, several conventional power plants can be avoided. At the rate of one MW per each eight acres, achievable by an optically-magnified PV system developer, the 5,700-acre old Magna Tailings Impoundment could produce (assuming 75% coverage to allow for support infrastructure) more than 500 MW. This would also cover the surface productively to render conventional reclamation by planting unnecessary (an advantage in an uncertain climatic future). High dump-plateau areas, the Barneys Canyon mine, and eventually the Bingham Pit, itself, could add another (theoretical) 10,000 acres at superior, high-altitude locations. The Barneys Canyon leach pads and some of the Eastside Dumps could add a similar amount. The Tooele County (west) properties may also be very productive. For the most part, adequate transmission lines are already in place. Startup is very rapid. *Power produced is all 'peak,' high-value power* because of its match to the daily demand cycle; this value difference can be used to finance capital costs. Estimated magnitude: At least 1,500 MW.
- ***Solar Thermal*** systems can produce either relatively low-grade heat for direct use, or electrical power. Multiple systems have been developed that offer potential at Kennecott's location:
    - Salt-gradient solar ponds (SGSP) capture solar heat in deep ponds engineered to create a brine layer in the bottom for heat capture, topped by a decreasingly briny 'density gradient' layer. The gradient prevents heat escape, with high efficiency. More academic and R&D work has been done for this technology on the Great Salt Lake area than on any other area of the world. Again, on the abandoned Magna Tailings Impoundment, as much as several hundred MW of electrical power could be produced, with significant quantities of heat also available to support heat-demanding industries and industrial parks located nearby (e.g., building materials manufacturing from tailings; see below). SGSP can also supply 'district heat' to nearby buildings and facilities of conventional design. This low-cost, low-tech technology is tolerant of cloudy periods and seasonal variations, allowing diurnal heat storage to generate electricity only at 'peak' times, if desired. *Water-treatment concentrates can be used as density-gradient salts,* allowing 'disposal' in SGSP as efficient alternatives to dumping concentrates into harm's way. SGSP systems have been operational and relatively trouble-free for many years at several locations around the world (see U Texas El Paso facility). Estimated magnitude: At least 500 MW on tailings ponds, with more possible on properties in Tooele County.
    - Solar concentrated-thermal systems utilize one of several concentrating mechanisms, which can consist of parabolic reflectors, heliostats (high-temperature concentrators) and so-called 'Stirling Engine' solar-gas hybrid engines to generate electricity at high

efficiencies. All of these are relatively high in investment requirements, but could provide high output on disturbed sites, putting them to highest-and-best use without significant further reclamation. Estimated magnitude: unknown; the "Pit," when mining ceases, could house several heliostats that would be larger than any in the world. Parabolic trough receivers of the "SEGS" type are now thought to be excellent prospective tech type. Magnitude unknown, and probably well into the future.

  - Hydropower potential exists while mining continues, in theoretical form at relatively large scale on the 1,500-foot descent of the Concentrator tailings line, and at smaller scale elsewhere. Pumped storage (a marginal 'renewable') could facilitate conversion of an as-happens energy source (e.g., wind at night) to 'peak' power production, with inevitable efficiency drops. Estimated magnitude: <50 MW.

- ***Distributed Renewables: Urban*** and industrial developments on Kennecott lands can, and should, seek to fully integrate PV, solar-thermal, passive solar, geothermal of multiple types, and as many other advanced renewable technologies as possible, seeking to make each facility as near to a net energy exporters as possible. 'District heating and cooling' can cluster users around highly efficient energy producing technologies to optimize scale and minimize transmission losses, preserving adaptability advantages of 'right-size' energy equipment. In business clusters or mixed-density residential areas, heating and cooling can be placed in nearly hidden central plants, utilizing systems (e.g., well-coupled geothermal, drawing on an area of Kennecott expertise, well drilling) that achieve extreme efficiencies.
- ***Towns and cities*** developed on Kennecott lands could be models of energy efficiency, by applying distributed renewable energy development and *high-performance building and infrastructure* design standards, feasibly achieving performance far beyond these systems for all building types.
  - US Green Building Council's 'LEED' certification system ("Leadership in Energy and Environmental Design"), applicable to many building types, with more certification systems to come soon for ones not covered now.
  - Sustainable Buildings Industry Council guidelines are particularly clear and useful for efficient homes design, but may also be applied to any other building type.
  - DOE 'Energy Star' program certifies homes and schools for energy efficiency.
  - A 'custom' certification system designed to fit company and community needs, either 'from scratch' or by overlaying additional requirements and incentives on top of USGBC's 'LEED' or 'Energy Star' (as proposed for Salt Lake City's 'High Performance Building Initiative').
  - Building-integrated energy producing systems, such as PV, solar thermal and wind. These are proven technologies, and they are descending in price.
  - Infrastructure, landscapes and buildings designed to reduce 'urban heat island' effects, achieving less demand for cooling energy.
  - 'District heating and cooling' systems, where clusters of businesses and/or residential buildings can share benefits of highly efficient technologies, such as ground-coupled or well-coupled heat pumps,
  - Industrial and commercial developments clustered along industrial ecology lines, 'cascading' energy and water through a business park complex to reduce energy (and water) consumption, and to approach zero discharge standards.

2. Tourism and Recreation, and Supporting Habitat-Forest Restoration. Utah's five National Parks and several National Monuments are complemented by National Recreation Areas, State Parks and recreation sites, and by other National Parks within a day's drive of Salt Lake City, to attract many millions of tourists each year from all over the world. In addition, the LDS Church center draws upwards of four million visitors per year, with relatively few 'day-trip' destinations other than skiing in the Wasatch Front region. The Wasatch Range has long been the most popular hiking, biking, horseback riding, picnicking and camping area, short of the Uinta Mountains 80-100 miles to the east. As population grows, the formally-designated watershed areas of the Wasatch are likely to be closed to many types of recreational access. These observations support planning of a cooperative, Oquirrh Mountains recreation area, integrating Kennecott lands into the picture of federal (BLM), state and other private ownership. Trails could be made to be as extensive as at a major National Park, but located within minutes of millions of residents, as well as the millions of visitors to the City. Great Basin National Park, by comparison, cannot promote the many forms of trails-based recreation that would be possible on the Oquirrhs, even as mining continues. Even off-highway vehicle users might have areas for sanctioned OHV recreation. As a fee-based system, this huge park would, inevitably, be a large employer and generator of revenues for the region through hospitality, sales, services and information.

In order for this to occur, significant forethought and design must go into

- demarcation of areas to avoid (other uses planned, including continued mining, renewable energy, urban development and public safety concerns;
- critical habitat areas and possible wildlife-human interactions;
- reforestation and revegetation plans, phased to allow designed, eventual access in some areas;
- fire prevention plans, particularly subject to climate change indications, if any.

Areas such as Soldier Flat and Little Valley may offer residential/mixed-use development potential place *within* this great recreation area, yet located within 15 miles of Salt Lake City's center. Views in all directions are superb, and the higher-altitude climate is very appealing, to be made moreso by reforestation, with an eye to fire hazard avoidance.

3. Materials Recovery: Several opportunities exist at Kennecott to complete materials 'loops,' to prevent ecological damages of great potential impact, and to take advantage of unused byproducts in huge quantities, for which significant investment has already been made.

- ***Autoclaved Aerated Concrete (AAC) from copper tailings:*** AAC is one of the world's best-established non-forest building materials, dominating the European market since about WWI in northern Europe. Approximately 38% of building wall assemblages in Germany and Sweden are built of AAC. AAC consists of a homogeneous foamed, lightweight cement block or panel, made with about 60% of its mass from a finely-ground silica mineral filler. A slurry is mixed of the mineral filler, cement, lime alumina and water, and cast into a large mold. After an initial 'set,' an oversized block is rolled out of the mold onto a conveyor, taken into a cutting area where very precise units are cut to exact dimensions. These units are then cured in an autoclave (by application of steam and pressure). They are dimensionally stable, excellent in insulation values and acoustic isolation, and unsurpassed in fire resistance. Precise enough to be placed quickly into setting beds of thinset mortar, AAC units can be field-cut with common carpentry tools to accommodate conduit and piping or reinforcement channels, and easily patched with cementitious or plaster compounds. High in thermal mass, AAC is creates thermally inert enclosures. It is also excellent in seismic performance, according to studies from Pennsylvania State's Materials Lab.

  AAC is being made in Arizona from copper tailings by a company called 'E-Crete' (http://www.e-crete.com/), which specializes in the use of copper tailings in AAC. A slight variation of the normal AAC manufacturing process, using high-productivity equipment pioneered and made in Germany, allows tailings to be an ideal mineral filler feedstock for AAC production. Technical evaluations show the tailings to be very suitable for this application in a quantity in excess of two billion cubic yards, and increasing rapidly.

  Salt Lake City's growth rate and geographic position in distribution networks to other rapidly growing urban areas render this a very marketable, very sustainable building material. Its architectural performance and environmental attractiveness are compounded by its potential to compete with dwindling supplies from threatened regional forests. Tailings-AAC may also offer price stability, which cannot be said of steel or wood products.

  AAC is heat-consumptive, using steam for curing. Were the Tailings Impoundment to be co-located with salt-gradient solar ponds or other solar-thermal installations, and with "CHP" (combined heat and power, or co-generation) to produce near-boiling temperature heat in large quantities, and electrical energy from this renewable source, the resultant AAC would be one of the world's most certifiably sustainable materials. If, as researchers suspect, the addition were made of chemical salts extracted from Kennecott's ground water contamination plumes, the AAC product may be significantly improved in compressive strength attributes.
- ***Selective metals and salts recovery from contaminated water.*** By one or a combination of separation technologies, Kennecott could feasibly reduce the disposal burden of contaminated ground water significantly, and develop some recovered materials as very marketable commodities. Experiments with 'biosulfide' (sulfate-reducing bacterially mediated, selective precipitation of metals), membrane filtration, evaporation-crystallization, distillation and other strategic technologies):
  - Copper concentrate
  - Alumina, catalyst grade or for use in AAC manufacturing, cement or concrete manufacturing
  - Gypsum for wallboard, plaster, or premium quality cosmetic or other applications
  - Other salts, some usable in complementary industrial developments (e.g., AAC strengthening), as gradient-inducing salts in solar ponds; most common salts in water treatment concentrates could be safely disposable into the Great Salt Lake, where water chemistry could be mirrored to

avoid ecosystem toxicity or imbalances. The exceptions are critical, however.

The alternative, simply to extract and dispose of contaminants --- fugitive liquid byproducts of the mining and leaching process in ground water --- placing eco-toxic compounds into or very near the Great Salt Lake (particularly selenium and certain other metals), violates a number of the sustainable development and sustainable mining principles reviewed earlier in this study, emphatically. Beyond that, it is tantamount to allowing an incomplete biogeochemical cycle on a very large scale to be left 'dangling,' waiving the opportunity to recover value in dissolved materials. All considered, this is as unsustainable a decision as this or any other mine could make, demanding 'offsets' and 'tradeoffs' under the *Breaking New Ground* MMSD Final Report, and even more under some of the other sustainability approaches reviewed here, putting recognition for sustainability into the realm of great difficulty, for seemingly little benefit, financial or otherwise.

- ***Aggregate mining*** from areas planned for specific development, or from disturbed areas, especially where on-site use can be made of road base and concrete constituent sands and gravels. This measure is environmentally justifiable, and will become more the case, as the population of the Valley develops farther westward. Aggregate extraction from east-side quarries can be avoided, as well, offering opportunity to preserve some areas of the Wasatch that would otherwise be severely impacted. The 'embodied energy' content of aggregates should be minimized by local production and avoided transport.

4. Land Use Conversion for Community 'Smart Growth': Kennecott's 143+ square miles of land contains an estimated 40-50 sq. mi. of industrial lands that may eventually be best utilized as energy producing areas, or for materials recovery. The remaining 90-100 sq. mi., however, includes at least 75 that are eminently convertible to a number of restorative or constructive land uses. Were this site far from cities, some canyons and valleys would be wonderful conservation areas; limited areas may turn out to be too steep or inaccessible for other uses, despite their physical beauty, and may become 'conservation easement' candidates (e.g., Harkers Canyon, Dry Fork Canyon, parts of Butterfield Canyon, Pine Canyon on the Oquirrh west side). The remaining areas, however, *are* near one of the most rapidly growing urban areas in the nation, whether we like the fact or not. Their 'highest-and-best' use follows from this adjacency.

Kennecott's leadership in altering the pattern assumptions about growth, the transportation system 'paradigm,' and expectations about energy performance in urban design and construction, is wonderfully beneficial. Kennecott Land Company has begun the consummation of a project that was initiated in the early 1990s, to examine ways that profitable land development could also benefit surrounding communities --- indeed, the entire region.

The large-scale Kennecott town development in South Jordan City, called 'Daybreak,' situated partially on the site of the old 1,300-acre South Jordan Evaporation Ponds, demonstrates what a well-conceived, compact-growth, mixed-use, walkable, transit-oriented development pattern can achieve. This plan will serve as the banner demonstration project for the region, and should be studied in depth by mines and other property owners with opportunities for land development. Populated by high-performance, energy-efficient, sustainable buildings, and reinforced by water-wise landscaping and interconnected open spaces and trails (ultimately connecting to the Oquirrh Mountains trails), a very different urban landscape will surround residents, businesses, students and workers in 'Daybreak.' Given the regional predilection for rapid population growth, this sort of land development 'trumps' most other potential uses of much of the Oquirrh foothills and mountain valleys. Towns and industrial/commercial developments do not have to preclude trails development, restoration of habitat areas, reforestation and recreational development in the Oquirrhs, however. Adequate, carefully-considered planning among appropriate stakeholders, fully considering the internationally-led standards and principles for sustainable mining, should lead to an enduring, responsible land use solution, not only on Kennecott's land, but also on that of adjacent landholders.

5. Community Development and Sustainable Jobs: Communities surrounding Kennecott have been the recipients of many billions of dollars of economic multipliers over the century + of mining here. Many, many of those historic communities are now gone. A tour of the adjacent communities, however, shows that they must be brought up several levels in their socio-economic expectations if they are to become neighbors conducive to Kennecott's land development potential. Affordable housing must become mixed equitably with housing and services to attract and support a wide range of incomes and resident types. Community institutions, supported conscientiously to some degree by Kennecott in the past, must be the foci of concerted investment, leadership and catalytic assistance.

Most of all, these communities need reasonably well paying, sustainable jobs and access to healthy and healthful environments. By exercising the entrepreneurial prerogative and making its resources and lands available, and by adventuring into the realm of creating a 'sustainable mining center' for the region and the world, Kennecott can begin to create jobs that will endure long after mining has finally gone away. Thomas Michael Power, the University of Montana economist and author of the book, *Lost*

Landscapes and Failed Economies: The Search for a Value of Place, convincingly shows how little economies in the West still depend on mining and other extractive industries. While this is true of mining in the conventional sense, sustainable mining postulated as community-centered, restorative, ecologically-conscious, entrepreneurial, capable of long-term/large-scale planning, and caring about its 'place,' may yet assume a far more significant role in the 'New West' of which we hear so much.

IE Steps toward Sustainable Mining Industrial Development: The work of E.A. Lowe (Indigo Development, www.indigodev.com) amply explores mechanisms and variations for business development in 'eco-industrial parks' (EIPs) and industrial ecology networks. The Kennecott case is sufficiently large and complicated, and so full of opportunity for business development around first, pollution prevention and environmental protection ('best practice) and second, resource recovery, renewable energy and land use development, that sustainable industries developments may require many EIPs, business clusters, and possibly clusters of clusters.

Eco-industrial development is best catalyzed by creation of a series of analyses, plans, organizational adjustments, policies, interventions in community economic processes, and entrepreneurial ventures.

- Identify core industrial activities and resources that create primary industrial development opportunities. Several of these have been discussed. (Renewable energy in several forms, tailings utilization for building materials manufacturing, recreational development around landscape restoration, etc.); recruit businesses for core IE development.
- Conceptualize 'the whole,' by identifying niche opportunities to complement core industries; recruit candidates for business development.
- Analyze and optimize theoretical flows (materials, energy) and capacity development prerequisites, including labor and labor practice changes required for success.
- Extend access to resources for development (e.g., tailings), and grant land access through outright grants or (for example) leases allowing costs to be minimized during startup, progressing in cost as profitability increases, or alternatively accepting profit share.
- Evaluate adequacy of financing mechanisms; devise plans for bridging any gaps for startup, without excessive control by EIP originating company.
- Assist in initial feasibility analyses, particularly in any laboratory or consultative costs encountered for technology evaluation and screening, maintaining involvement to help assure that early mistakes are avoided.
- Devise contractual and legal relationship framework to allow mutually beneficial business collaborations and ongoing cooperative management in EIPs; draw on models in progress elsewhere in the world for optimization of flexibility within framework of adequate protections against possible faults that can be reasonably anticipated.
- Establish investor network, guidance, or venture capital fund to attract 'socially responsible investment' or conventional venture investment in EIP; established company name and leadership can overcome many barriers to investment attraction and accelerate business development significantly.
- Establish eco-industrial 'incubator' to assist business startup, management and maintenance; conduct training workshops or other assistance activities to catalyze core and niche business competence and probability of success.
- Assist in setting up 'by-product exchange' (BPX) or other cooperative resource flow management mechanisms.
- Assist in planning and creation of high-performance facilities for EIP members, assuring efficient operations and low overhead, as well as low environmental impacts.
- Assist in marketing strategy development in EIP, and in marketing startup.
- Utilize advantageous products in company projects (e.g., tailings AAC in town developments on company land, synergistically producing high-efficiency buildings while assuring steady market conditions for startup of AAC manufacturing, as well as labor force training for use of new materials).
- Assist in establishing institutions and management structures for EIP self-maintenance, monitoring and management, and to help EIP to attract investment, R&D capacity, and regulatory accommodations to be able to operate without undue impedance from government.
- Help to promote EIP and company sustainability efforts regionally, nationally and internationally. Assist with marketing at all levels, utilizing existing company and parent company liaison and resources.
- Work with community stakeholders and business participants to assure that community needs and desires and honored, and that a long-term vision for community benefit is fully integrated into EIP adaptive management plans.
- Commission ecological analyses and reviews to assure that best environmental choices are being pursued, and that 'highest-and-best' utilization of byproduct material and energy flows is being achieved.
- Invest in ongoing capacity development and community learning to further development of the

overarching 'whole mine – whole community – whole planet' sustainable mining initiative through universally shared learning opportunities, helping the community to envision its own place and how further initiatives may be developed to leverage opportunities and benefits created.

Conclusions

Kennecott can "break new ground" by assembling a 'whole mine – whole community – whole planet' package of adaptable, sustainable development that is responsive to community and ecosystems at local, regional and global levels. The profit potential of such a plan is unexplored territory, but if boldly pursued, offers potential of many different types and levels of benefits.

A customized 'tool-kit' --- or perhaps miners would feel more comfortable calling it a 'spread' (industry expression for assemblages of "yellow iron," the color of favorite heavy earthmoving equipment) --- is certain to be the most effective way to envision, articulate, plan , design and execute its sustainable mining future. As our review of international sustainable development and sustainable mining thinking seems to agree, pre-formulated, off-the-shelf methodologies may mislead and fall short of what can be achieved by a 'tailor-made' approach. Whatever the method, a mindset must be adopted that embraces 'place' and circumstance in its totality, including probable futures. It is the redirecting of those interrelate futures to which sustainable development must direct itself, at Kennecott Utah Copper as at every other mine in the world.

'Eco-industrial parks' (EIPs) may be advantageous at multiple Kennecott locations, particularly around the tailings impoundment, the Bingham Mine and other renewable energy production centers, and at gateways to future Oquirrh Mountain recreation and tourism areas. Consisting of clusters of collaborating industries located together for superior energy, material and water efficiencies, limitation of environmental impacts, and for marketing advantage, EIPs seek to create institutional intelligence and memory, constructing community-centered solutions to community challenges and opportunities. Kennecott leadership and assistance can make great differences in overcoming early barriers, especially investment, recruitment and legal/regulatory accommodations.

Hypothetical EIP: Magna Eco-Industrial Park.

A vision of an industrial cluster that operates toward objectives of industrial ecology can go a long way toward accomplishing objectives being developed by the international sustainable mining initiatives, as well as those described in generalized sustainable industrial development works reviewed here.

A model EIP might be established around core functions, locating at one of the of the Magna Tailings Impoundment corners (southwest might be best, near the former town of Garfield), near Magna (12 miles west of Salt Lake City), close to highways and rail transportation:

- **Renewable energy production** on the Magna Tailings Impoundment, both from solar-concentrated PV and from salt gradient solar ponds (SGSPs), producing both 'peak' electrical power and base power, and generating heat for direct use, supplemented by landfill gas, with natural gas available as a fallback until methane generation from anaerobic digestion can be made adequate in the EIP. (Avoided costs for tailings surface reclamation and air quality violations avoidance must be included in benefit calculations.)
- **Tailings autoclaved aerated concrete (AAC)** manufacturing, preferably at a pilot plant rate of approximately 1,000 cu.m./day, using heat and electrical power from renewable energy generated from the Tailings Impoundment. Water would be supplied by a water treatment plant within the EIP.
- **Water by-products recovery** plant would selectively recover metals and salts constituents from ground water, either treating the various waters at this geographic low point of the remediation system, or treating concentrates from membrane filtration at other locations. Water recovered by distillation or another appropriate process would be used in AAC manufacture. Heat from salt gradient solar ponds would be used to increase efficiency of water treatment, either by energy inputs to distillation or by decreasing viscosity of water in membrane filtration, or both. Alumina recovered from acid/metals ground water and 'meteoric leach water' from around the mine would be utilized partially in AAC manufacture, as would sulfates, some gypsum, lime and certain other recovered salts. Density-gradient salts for the salt gradient solar ponds would be recovered from water or membrane filtration concentrates, avoiding disposal costs and sequestering salts until processing to remove metals, selenium and other components with commodity value or potential to damage ecosystems. Salts to 'mirror' Great Salt Lake chemistry could be released to the Lake, subject to guidance from environmental regulatory officials.
- **Greenhouses and Aquaculture** on an industrial scale would propagate plants appropriate for landscape restoration of Kennecott's northern Oquirrhs areas, as a first priority, and cultivate horticultural products (vegetables, herbs) for export and for regional organic food markets, supplemented by flowers, especially cut-flowers, for high-value markets. Heat and water would be drawn from SGSPs, AAC manufacturing (excess steam) and from water by-products recovery. Water

and energy 'cascading' can be engineered among these major functions, avoiding treatment between or among businesses more than is necessary, and sharing energy flows.

- **Residences and commercial mixed-use development:** Given zero-discharge 'best practice' standards for all EIP industries, and given regulatory cooperation for co-location, great efficiencies could be constructed in an EIP-town development drawing on tailings AAC as a major building material, and on 'district' heat and cooling utilizing SGSP and industrial energy flows. Jobs for residents and niche business development or recruitment opportunities will inevitably accrue.

Second-Circle EIP Functions: Around these core complementary functions, the recruitment and cultivation of 'niche' activities and human inventiveness can 'grow' the economic diversity and vitality of the EIP system and its interactions with other regional systems. With the objective of capacity development, labor skills training, further entrepreneurship, research and development, and basic technology studies and sciences, a cluster of complementary activities would be beneficial, some of them necessary:

- **EIP 'Incubator' and investment center:** Leveraging Kennecott's 'brand' and credibility for attraction of venture capital is a critical contribution Kennecott and Rio Tinto could make to EIP development, and thereby to the 'whole mine – whole community – whole planet' concept of sustainable mining. An incubator assists in the creation and growth of EIP industries/businesses at all scales, from core to niches, from industry to training and capacity development. 'Socially-responsible investing' has become an internationally significant area of investment, an investment segment for which a Kennecott EIP for sustainable mining would be extremely attractive, given the uniqueness of such an initiative. Participating businesses would need:
    - **Access to resources** on a dependable basis, such as tailings for AAC, renewable energy, transportation facilities, and especially land for facilities development.
    - **Business startup and management assistance**, including 'pool' office space, bookkeeping, accounting, and business counseling services; models elsewhere provide graduated rent and profit-sharing to encourage aggressive but responsible transitions to independent operation within a few years, based on contractual relationships.
    - **Market analysis and planning, marketing and media** assistance and guidance. 'Pool' cooperative marketing could advance each EIP component rapidly, together, much more affordably than otherwise, assisting not only the individual ventures, but also the EIP as a whole, benefiting Kennecott and its sustainable mining initiative.
    - **Technological analysis and process optimization,** including engineering, laboratory analysis at affordable rates, monitoring at frequencies required by process startup and optimization, and other R&D services, especially to establish highest-and-best EIP 'complementarity' of functions.
- **EIP management and study center**, where industrial ecology monitoring, analyses, planning, marketing and development are focused. This center becomes the institutional memory and dynamic intelligence of this cooperative, collaborative industrial/business center.
- **Landscape restoration and management** enterprises, planning and managing the planting of damaged lands, possible sustainable forestry initiatives for trees in *de facto* plantations along trails and around communities in foothill areas, from which selective harvesting could occur within 20 or so years; phytoremediation applications, possibly developing mycorrhizal inoculation as a strategy to uptake metals into harvestable plant mass for relocation and metals recovery in processes developed in the EIP; and landscape planning and implementation to complement Kennecott's town development programs in Oquirrh foothills areas.
- **Bio-energy development** to provide sustainably generated fuels for the EIP, and to convert organic municipal wastes, and possibly sewage treatment sludges, for conversion to energy, probably by anaerobic digestion, gasification, pyrolysis or some strategic combination of all.
- **Mining urban waste and resource recovery center** could begin the inevitable process of finding technologies and practices to make urban resource flows and past urban waste into a profit- and resource recovery-center. Construction waste has been converted to salvaged resource recovery elsewhere, and is being converted at relatively small scales in our area. Nearby construction waste landfills could be involved in EIP resource recovery enterprises.
- **Gypsum wallboard, plaster and secondary building materials manufacture** could utilize gypsum from water treatment that is not captured for other uses, and could coordinate with other resource recovery to explore creation of new recycled materials and systems, such as 'structural insulated panel' (stressed skin panel) building systems, which are high-performance systems for great energy efficiency, possibly complementing AAC systems.

- **Renewable energy development center** would strive to optimize and perfect PV, SGSP, solar-thermal, building-integrated renewables (e.g., passive solar, earth-coupled and well-coupled geothermal, PV for buildings, solar water heating, etc.) and to train vendors and contractors in applications, installation and maintenance. District heat and cooling for Kennecott developments could be a primary activity of this enterprise, providing 'bundled' utility services to residents and commercial tenants.
- **High-performance building applications center** would develop optimal applications systems for use of AAC, renewable energy, and best-practice approaches to community design, both for application within Kennecott's land holdings and in the region. A study center offering appropriate certifications for mechanical systems, a training center for AAC product installation
- **Industrial efficiency engineering and process development center** would be highly desirable to optimize EIP and ongoing Kennecott processes, all the way from achieving 'zero-discharge' best-practice standards in each EIP 'organism,' but also in furthering EIP inventiveness for creation of investment advantages for marketing outside the EIP. Energy efficiency through full utilization of efficient motors, lighting, space heating, process energy and energy recovery (CHP); materials and resource flows analysis, and implementation of findings to optimize materials and water use efficiencies.
- **Tourism and 'eco-tourism' visioning, planning and development center:** With the enormous opportunity of recreation development on the Oquirrh Mountains, in the context of continuing mining, abandoned (but hazardous) facilities left essentially forever, habitat and ecosystem restoration areas, federal and other private lands, and the possibility of human-wildlife interactions, planning is imperative. Some 'point' attractions could be developed, such as 'view pavilions' or even restaurants or hostels, on peaks where some of the best views in the West are available. Trams have been studied to convey visitors to those points, but much more work is necessary, coordinated also with base centers, where museums or mining history centers could be located. Renewable energy and landscape restoration so close to the city center will become attractions for some portion of the millions of visitors each year, in addition to the growing populations of residents.
- **Great Salt Lake, Great Basin and Lake Bonneville studies center:** Pre-history, paleoecology, archeology and history of the area are so rich and vivid that they could easily form an anchor for academic investigations on Kennecott property areas previously closed to investigations, and into the Great Salt Lake ecosystem and its condition, particularly as it is more densely surrounded by urban development and conventional industries. 'Industrial archeology,' in itself, could become a core realm of inquiry, producing a fascinating museum of pre-mining, mining and post-mining experience.

References

<u>Sustainable Mining:</u>

1. Berger, Alan 2002, Princeton. *Reclaiming the American West.*
2. C.L. Brierley, 1982. "Microbiological Mining," in *Scientific American* V. 247 No. 2, Aug. 1982.
3. MMSD, IIED, WBCSD, 2002. *Breaking New Ground: The Report of the MMSD Project.* R. Sandbrook, Project Coordinator.
4. MMSD, IIED, WBCSD, 2002. *Mining for the Future, Main Report*, D. Van Zyl, M. Sassoon, C. Digby, A.-M. Fleury & S. Kyeyune.
5. MMSD, IIED, WBCSD, 2002. *Finding the Way Forward: How Could Voluntary Action Move Mining Towards Sustainable Development?.* J. Walker, S. Howard.
6. MMSD, IIED, WBCSD, 2002. *Room to Manoeuvre? Mining, biodiversity and protected areas.* I. Koziell, E. Omosa.
7. MMSD, IIED, WBCSD, 2003. *Finding Common Ground: Indigenous Peoples and their Association with the Mining Sector.*
8. MMSD, IIED, WBCSD, 2001. *Artisanal Mining in the People's Republic of China.* A.J. Gunson, Yue Jian.
9. MMSD, IIED, WBCSD, 2002. *Sustainability Indicators and Sustainability Performance Management.* A. Warhurst.
10. MMSD, IIED, WBCSD, 2002. *The Life Cycle of Copper, its Co-Products and By-Products.* R. Ayres, L. Ayres, I. Rade.
11. United Nations, 1995. *Mineral Recovery, Recycling, Waste Prevention and Confinement for Sustainable Development in Asia the Pacific Region.*
12. United Nations, 1997. *Towards Sustainable Minerals Supply in the Asian and Pacific Region: Review of Emerging Mineral Policies and Development Activities.*
13. World Bank, IDRC, 2001. *Large Mines and the Community: Socioeconomic and Environmental Effects in Latin America, Canada, and Spain.* G. McMahon, F. Remy, eds.

Industrial Ecology:

14. Robert U. Ayres, Leslie W. Ayres, 1996. *Industrial Ecology: Towards Closing the Materials Cycle.*

15. T.E. Graedel, B.R. Allenby, 1995. *Industrial Ecology.*

16. E.A. Lowe, J.L. Warren, S.R. Moran, 1997. *Discovering Industrial Ecology: An Executive Briefing and Sourcebook.*

17. E.A. Lowe, J.L. Warren, D.B. Holmes, 1998. *Eco-Industrial Parks: a handbook for local development teams.*

18. E.A. Lowe, 2001. *Eco-Industrial Park Handbook for Asian Developing Countries: A Report to the Asian Development Bank.*

19. S.E. Manahan, 1999. *Industrial Ecology: Environmental Chemistry and Hazardous Waste.*

20. D.J. Richards, ed. 1997. *The Industrial Green Game: Implications for Environmental Design and Management.* National Academy of Engineering.

21. R. Socolow, C. Andrews, F. Berkhout, V. Thomas, 1994. *Industrial Ecology and Global Change.*

22. United Nations Environment Programme Industry and Environment, 1997. *The Environmental Management of Industrial Estates.*

Sustainable Development:

23. S. Aroni, G.J. de Groot, M.J. Robinson, G. Svanholm, F.H. Wittman, 1993. *Autoclaved Aerated Concrete: Properties, Testing and Design.*

24. T. Beatley, K. Manning, 1997. *The Ecology of Place: Planning for Environment, Economy, and Community.*

25. T. Beatley, 1994. *Habitat Conservation Planning: Endangered Species and Urban Growth.*

26. Beaton, R., C. Maser, 1999. *Reuniting Economy and Ecology in Sustainable Development.*

27. M.K. Briggs, 1996. *Riparian Ecosystem Recovery in Arid Lands: Strategies and References.*

28. S. Cunningham, 2002. *The Restoration Economy: The Greatest New Growth Frontier.*

29. G.C. Daily, K. Ellison, 2002. *The New Economy of Nature: the Quest to Make Conservation Profitable.*

30. V.H. Dale, M.R. English, eds., 1999. *Tools to Aid Environmental Decision Making.*

31. H.E. Daly, K.N. Townsend, eds., 1993. *Valuing the Earth: Economics, Ecology, Ethics.*

32. R. Dorfman, N.S. Dorfman, 1977. *Economics of the Environment.*

33. Earthpledge Foundation, 2000. *Sustainable Architecture White Papers.*

34. P. Ekins, M. Hillman, R. Hutchinson, 1992. *Gaia Atlas of Green Economics.*

35. A.M. Evans, 1997. *Economic Geology and its Environmental Impact.*

36. C. Frankel, 1998. *In Earth's Company: Business, Environment and the Challenge of Sustainability.*

37. A. Gedricks, 1993. *The New Resource Wars: Native and Environmental Struggles against Multinational Corporations.*

38. P. Gipe, 1995. *Wind Energy Comes of Age.*

39. P. Hawken, 1993. *The Ecology of Commerce: A Declaration of Sustainability.*

40. P. Hawken, A. Lovins, L.H. Lovins, 1999. *Natural Capitalism: Creating the Next Industrial Revolution.*

41. T.B. Johnansson, H. Kelly, A.K.N. Reddy, R.H. Williams, eds., 1993. *Renewable Energy: Sources for Fuels and Electricity.*

42. C. J. Kibert, J. Sendzimir, G.B. Guy, eds. 2002. *Construction Ecology: Nature as the Basis for Green Buildings.*

43. C.J. Kibert, ed., 1999. *Reshaping the Built Environment: Ecology, Ethics, and Economics.*

44. R.J. Komp, 2001. *Practical Photovoltaics: Electricity from Solar Cells..*

45. Land and Water Fund of the Rockies, The Energy Project (now Western Resource Advocates), 1996. *How the West Can Win: A Blueprint for a Clean & Affordable Energy Future.*

46. J.T. Lyle, 1994. *Regenerative Design for Sustainable Development.*

47. C. Maser, 1999. *Ecological Diversity in Sustainable Development: The Vital and Forgotten Dimension.*

48. C. Maser, R. Beaton, K. Smith, 1998. *Setting the Stage for Sustainability: A Citizen's Handbook.*

49. C. Maser, 1997. *Sustainable Community Development: Principles and Concepts.*

50. W. McDonough, M. Braungart, 2002. *Cradle to Cradle: Remaking the Way We Make Things.*

51. W.J. Mitsch, S.E. Jorgensen, 1989. *Ecological Engineering: An Introduction to Ecotechnology.*

52. B. Nattrass, M. Altomare, 1999. *The Natural Step for Business.*

53. S. Peck, 1998. *Planning for Biodiversity: Issues and Examples.*

54. D. L. Peterson, V. T. Parker, eds., 1998. *Ecological Scale: Theory and Applications.*

55. T. M. Power, 1996. *Lost Landscapes and Failed Economies: the Search for a Value of Place.*

56. H. Robert. *The Natural Step.*

57. Rocky Mountain Institute, 1998. *Green Development: Integrating Ecology and Real Estate.*

58. J.J. Romm, 1999. *Cool Companies: How the Best Businesses Boost Profits and Productivity by Cutting Greenhouse Gas Emissions.*

59. N.J. Roome, ed., 1998. *Sustainability Strategies for Industry: The Future of Corporate Practice.*

60. W.H. Schelesinger, 1991. *Biogeochemistry: An Analysis of Global Change.*

61. P.C. Schulze, ed., National Academy of Engineering, 1996. *Engineering within Ecological Constraints.*

62. J. Silberstein, C. Maser, 2000. *Land-Use Planning for Sustainable Development.*
63. V. Smil, 1985. *Carbon Nitrogen Sulfur: Human Interference in Grand Biospheric Cycles.*
64. V. Smil, 1997. *Cycles of Life: Civilization and the Biosphere.*
65. D.S. Smith, P.C. Hellmund, eds.1993. *Ecology of Greenways: Design and Function of Linear Conservation Areas.*
66. P.F. Smith, 2003. *Sustainability at the Cutting Edge: Emerging Technologies for Low Energy Buildings.*
67. T. Tietenberg, 1984. *Environmental and Natural Resource Economics.*
68. S. Van der Ryn, P. Calthorpe, 1986. *Sustainable Communities: A New Design Synthesis for Cities, Suburbs and Towns.*
69. S. Van der Ryn, S. Cowan, 1996. *Ecological Design.*
70. F. Wagner, ed., 2002. *Preparing for a Changing Climate: Rocky Mountains/Great Basin.*
71. S.G. Whisenant, 1999. *Repairing Damaged Wildlands: A Process-Oriented, Landscape-Scale Approach*
72. J.R. Wilcox, L. Theodore, 1998. *Engineering and Environmental Ethics: A Case Study Approach.*
73. J.E. Young, 1992. *Mining the Earth.*

Kennecott Ecological Studies:

74. J.F. Blanchard, Jr., 1973. *An Ecologic and Systematic Study of the Birds of the Oquirrh Mountains, Utah.* M.S. Thesis, U. of Utah.
75. Kennecott Utah Copper, Ecological Planning and Toxicology, Inc., 1996. *Ecological Risk Assessment Northern Oquirrh Mountains: Final Report.*

Figure 1: Kennecott and Oquirrh Mountains Site