Biotechnology: sustainability's silver bullet

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ABSTRACT

While the average global citizen's carbon footprint on the world seems to be growing, the actual carrying capacity of the world is declining as natural resources are diminishing. Fortunately, in addition to government intervention, media attention, and financial scrutiny, powerful external coalitions are emerging to champion sustainability. Progress, however, is inconsistent and unpredictable. A competing values framework is presented as well as a buffet of green initiatives and biotech potentials for clean brown, shrink brown, build green, and grow green strategies. Green initiatives are often cost intensive, and even cost prohibitive, in pollution intensive industries. Without biotechnology, going green is likely to remain relatively ineffective because only biotech advances hold the promise of developing green products and services that are genuinely competitive "best value" offerings, or in some cases, even cost efficient. Once this happens, green will become best practice, and markets and industries will be transformed.

Keywords: Biotechnology, sustainability, green initiatives, greening of management

INTRODUCTION

By the late 1990s, it was widely agreed upon in the scientific community that increased levels of carbon dioxide and greenhouse gases were creating larger problems that would eventually result in catastrophe. Unfortunately, there were still "many consumers and policy makers [who] seemed to ignore warnings of catastrophic climate change" (Billitteri, 2008, p. 994). Some of the most alarming global trends include**:** more species becoming endangered and/or extinct, plummeting biodiversity levels, increasing deforestation, loss of arable farmland, disappearing aquifers, increasing desertification, and growing oceanic dead zones. (Black & Phillips, 2010) While more and more often, the average global citizen's carbon footprint on the earth is growing, the actual carrying capacity of the world is declining as more and more of its natural resources are used. The issues surrounding the overconsumption of non renewable resources, polluting of waterways, overfishing of oceans and disposing, instead of recycling, of waste are issues that must be overcome in this lifetime. If all wealth comes from the earth, then in order to be wealthier overall, human beings must sustain the earth. (Anderson & White, 2009; Lin & Ho, 2010; Kohnen, 2009)

The purpose of this paper is to present the case for biotechnology as a beacon of sustainability for green managerial efforts. In so doing, a competing values framework as well as green initiatives and biotech potentials for clean brown, shrink brown, build green, and grow green strategies are examined.

THE GREENING OF MANAGEMENT

Fortunately, powerful external coalitions are emerging to champion sustainability. Today's environmental movement is gaining the support of many groups who, in the past, did not show public support for environmental issues including republicans, religious groups, conservatives, and laborers (Price, 2006; Hirsch, 2006). In a 2008 poll conducted by ABC News/Planet Green/Stanford University, 71% of participants are reducing their carbon footprint. Of these participants, 33% of them are reducing their carbon footprint to improve the environment, 24% are doing so to save money, and 41% are doing so both to save money and to improve the environment. These results highlight the increasing desire of consumers to reduce their carbon footprints and improve the overall health of the environment. In addition to their own conservation and recycling efforts, many consumers are choosing products that are marketed as being green, or environmentally friendly. (Langer, 2008)

To respond to consumers' desires to reduce their carbon footprints, managers in turn are increasingly becoming more focused on green. The greening of management is the recognition of the link between the organisation's decisions and activities and its impact on the natural environment (Smith, 2010).

> "Environmental regulations, such as the laws governing clean air, water, and land establish minimum legal standards that businesses must meet. Most companies try to comply with these regulations, if only to avoid litigation, fines, and, in the most extreme cases criminal penalties. But many firms are now voluntarily moving beyond compliance to improve environmental performance in all areas of their operations. Researchers have sometimes referred to the process of moving toward more proactive environmental management as the greening of management. Green management can improve a company's strategic competitiveness." (Mir, 2010, p. 1)

Why are managers becoming more green? One aspect of it is responding to their customers. However, businesses also are wanting to avoid governmental intervention, get with the popular media bandwagon, and enjoy the financial benefits and scrutiny of going green.

Governmental Intervention

Governmental concern has resulted in both national regulation and international agreements among most developed countries. The first large-scale environmental conference was organized by the United Nations and held in Stockholm, Sweden in 1972. This was followed by a series of *Earth Summit* conferences in 1992, 1997, and 2002. The tangible transformations that evolved from these summits are apparent in systems such as the International Organization for Standardisation's (ISO) 14,000 guidelines that established standards for environmental management in business (EMG, 2008). Further agreements on environmental issues such as greenhouse gas emissions are in negotiation.

According to the United Nations Educational, Scientific, and Cultural Organization, "Sustainable development is seeking to meet the needs of the present without compromising those of the future generations" (UNESCO, 2010, p. 1). Sustainable development must play a more prominent role as populations worldwide grow and the demand for infrastructure and resources increases. The United Nations Secretary-General, Ban Ki-moon stated, "Among the most significant implications of the shift to a greener economy is its potential to mitigate climate change and assist countries in coping with its growing impacts" (UNEP, 2009, p. 1).

Media Attention

More of the potentially devastating impacts on the world, such as increased climate change and reaching the Earth's tipping point are being discussed in popular documentaries such as former Vice President Al Gore's *An Inconvenient Truth*. Gore brought global climate change into the international spotlight by addressing the growing perils and dangers existing from rising greenhouse gas emissions, and won a Nobel Prize for his efforts (Billitteri, 2008). With this film came greater recognition from countries around the world that changes must soon be made in order to ensure the availability of natural resources for future generations.

Media commentators have found some success championing environmental issues. For example, Russell Mokhiber helped bring environmental criminals more into the spotlight when he published his list of the "Top 100 Corporate Criminals of the Decade" an article regarding the 1990s. This list helped to dispel the myth that environmental crimes are not considered extremely important. Of the 100 corporate criminals Mokhiber listed, 38 were categorized as crimes related to the environment (Mokhiber, n.d.).

Financial Scrutiny

Increasing numbers of investors are placing their money in socially responsible and environmentally sustainable funds and corporations. In 1999, the Dow Jones Indexes created the Dow Jones Sustainability Indexes (DJSI, 2008), which evaluates whether the strategy and operations of publically traded businesses take the environment into consideration, as well as financial success, customer and product relationship, corporate governance and stakeholder engagement, and human resources programs. According to Chang (2009, p. 1), "More than 570

asset owners and investment managers who control more than $18 trillion in global assets have signed on to the UN's Principles for Responsible Investment (UNPRI)." With so many asset owners investing sustainably, it is clear that socially responsible investments have become more main stream and have earned a permanent place in the investment world. Financial areas which have begun to expand to green investments include multilateral financial institutions, public sector pension funds, foundations and endowments, environmental nongovernmental organizations, organized labor, and company pension funds (Kiernan, 2009). Increased interest has spawned a new generation of independent business websites systematically evaluating and scoring sustainability. For example, KLD Research and Analytics (2007) lists the stocks of the 20 most sustainable publicly traded businesses for investor's reference. Consequently, environmental sustainability and sustainable competitive advantage are finding common ground.

Progress, however, is inconsistent and unpredictable. Five of the signatories of the UNPRI were recently expelled for failing to issue reports which should have detailed newly implemented guidelines with respect to sustainability measures. These failures can most likely be attributed to the lack of professionals who also have the sustainability knowledge necessary to implement and monitor such changes needed to fall within the UNPRI's guidelines. (Chang, 2009)

Most attention in going green focuses on the design, manufacture, and delivery of products and services. As a result, "the patenting of biotech is still changing and much uncertainty remains in the patent world, it is apparent from the recent decisions (which collectively may act as a barometer of judicial sentiment) that patentability will depend less on biology and more on technology" (Wu, 2010, p. 232) The segments of the value chain, and the external forces which impact them, are profiled in Figure 1.

All of the incentivizing external forces - public goodwill, government incentives, funding reserved for green firms, liability issues, and government regulations - can be offset by the differential costs of going green. Research suggests that compliance costs, while varied, are often significant and increasing, particularly in pollution intensive industries (Widmer, 2001). Nor is financial support for such costly efforts forthcoming from some segments of the financial market, such as foreign investors. There is empirical evidence that environmental compliance costs have a large, widespread negative effect on foreign investment in US pollution intensive industries (Keller & Levinson, 2002).

Governments are most concerned with competitiveness. Passing legislation which mandates cuts in emission rates and energy consumption can force some companies entirely out of business. Many alternative sources of energy are more costly than traditional sources, require the purchase of new equipment, and involve a great deal of man hours to develop new systems to be in line with the law. Some companies choose to cut jobs, dividends, research and design investments, and other areas in order to come up with the money needed to buy new equipment to be green. As Hazell (2009, p. 11) explains, it has seemed that many government agencies are "reluctant to talk about losing industries and brown jobs in their green jobs strategies." This is because it would be impossible for all job sectors to benefit from the need to operate industries in a more sustainable manner. With new caps on emissions, there would likely be increased costs associated with vacationing and tourism, long-distance trucking and shipping, airfare, and oil sands development (Hazell, 2009).

THE GREEN BUFFET

There is no consensus on how to best achieve sustainability. Corporations not only engage in a wide array of initiatives, but their performance is seldom comprehensive -- they are strong in some areas, and need improvement in others. Differences in these perspectives will be captured using a "competing values" model, which illustrates the inherent paradox involved in most business operations (Quinn & Rohrbaugh, 1983; Quinn, 1988). Quinn and Rohrbaugh's classic model has been summarized in Figure 2. This model can be adapted to capture the tensions between different perspectives on going green. Sustainability initiatives can be clustered on two dimensions: an internal versus external focus, and by innovation versus efficiency, as illustrated in Figure 3.

An internal versus external focus assesses the degree of change an organization is willing to invest in. An external focus directly targets environmental improvements and implements whatever changes are necessary to realize that goal. An internal focus is more incremental, involving upgrades to the current operation to be as green as possible, instead of transitioning towards new systems explicitly designed with green in mind.

Innovation versus efficiency assesses the proactive versus reactive responses of the organization. Efficiency is more remedial, and involves reducing existing problems, such as waste and pollution. Innovative initiatives are more proactive, involving new technologies and eco-friendly alternatives, with the ultimate goal of preventing "brown" problems in the first place, instead of accepting them as inevitable and minimizing their impact.

Clean Brown

The upper-left quadrant involves strategies focusing on reducing the negative ecological impact of current operations - in short, cleaning up the mess. This usually involves filtering emissions and effluent to remove some of the toxins, and then containing those that escape into the environment. This area is the focus of most legislation, as regulated by the Environmental Protection Agency [EPA]:

> "The Office of Pollution Prevention and Toxics (OPPT) was formed in 1977 with the primary responsibility for administering the Toxic Substances Control Act (TSCA). The law's goal is to ensure that chemicals sold and used in the United States do not pose an unreasonable risk to human health and the environment. The law covers production and distribution of commercial and industrial chemicals. Under TSCA, EPA has established reporting, record-keeping, testing, and control-related requirements for new and existing chemicals." (OPPT, 2010, p. 1)

Shrink Brown

While cleaning up the direct and indirect pollution caused by production is important, mainstream efficiency efforts reduce pollution by reducing consumption and waste generation. Efficient processes, such as "lean" manufacturing initiatives minimize resulting waste through continuous innovation (Wilson, 2009). Since such initiatives tend to favorably impact the bottom-line, securing management support for funding, and even education and training, is relatively straightforward. Initial costs of necessary green equipment easily pay for themselves over the long run. For example, Wal-Mart has been able to cut costs and increase profits by

implementing efficient business practices within their organization. Simple changes like cutting down on the idling times of fleet vehicles, reducing excess packaging, and cutting consumption rates of fuel and water cut costs and shrink company expenses. (Price, 2006) For example, Wal-Mart is making some simple changes:

> "When it applies to supply-chain management, the savings from life-cycle analysis can be dramatic. Part of Wal-Mart's sustainability program, for example, calls for suppliers to 'reduce packaging by 5% by 2013.' Smaller packages mean more units per cargo carrier, which means fewer cargo carriers. The company estimates it will save 667,000 metric tons of carbon dioxide from being released and 66.7 million gallons of diesel fuel." (Wasik, 2010, p. 1)

Build Green

Beyond efficiency lies innovation. At the very least, organizations can audit their suppliers, processes, and products, and whenever possible, replace high polluters and non-renewable resources with more eco-friendly alternatives. Low energy fluorescent bulbs and low water toilets can be installed, packaging can be made compostable, crop purchases can focus on organics, trash can be sorted and recycled, and renewable natural products can replace non-renewable petroleum derivatives. These savings then can be passed onto consumers, who are able to purchase products at savings of up to 70% off of competitors who do not use recycled or refurbished materials (Perman, 2006). Packaging this approach has proven to be, in and of itself, a viable, sustainable, competitive advantage, as Whole Foods has demonstrated:

> "For example, who are we? Well, we seek out the finest natural and organic foods available, maintain the strictest quality standards in the industry, and have an unshakeable commitment to sustainable agriculture. **...** Whole Foods **—** We search for the highest quality, least processed, most flavorful and natural foods possible because we believe that food in its purest state — unadulterated by artificial additives, sweeteners, colorings and preservatives — is the best tasting and most nutritious food there is." (Whole Foods, 2010, p. 1)

Grow Green

The proactive organization goes further by adding and pursuing innovations to accomplish green goals. Instead of merely adopting green technologies and products, they help develop them. Currently the popular focus is on switching from a dependence on fossils fuels to renewable energy. From this perspective, there is no time to wait, as many decades of environmental degradation have put the world on a frighteningly fast pace for extreme ecological problems in the coming years.

> "As an emerging technology migrates from concept to product to market acceptance, a well-functioning oversight system will shape its approach differently for each phase. With research and development being the most fraught with unknowns, the approach should be precautionary in the science but limited in public participation. As a product enters the regulatory phase, prudent scientific scrutiny, accompanied by a large role for public input, is likely to be the most appropriate. Once a product enters the market, public involvement in its acceptance should be aided by credible persuasion.

> "The attributes identified by the authors need to run through all three phases, but their relative roles shift with each phase, and the remedies for correcting mistakes or preserving options change in ways that should protect the integrity of the system while minimizing the costs and disruptions. An oversight system that modulates as a product moves through it will not resolve all questions or doubts, but it stands the best chance of getting the mix of attributes attuned to the full range of society's interests." (Johnson, 2009, p. 593)

As Hazell (2009, p. 11) explains, "Sudden dramatic and catastrophic events are expected to become increasingly frequent, so the transformation to a sustainable, green-jobs economy may need to be non-linear." However, industry is responding. For example, General Electric has invested over $1.5 billion in research and design for more efficient technologies (Price, 2006).

BIOTECH'S POTENTIAL

Biotechnology is a broad term encompassing everything from the use of microorganisms in the fermentation of food products to the recombinant DNA technology utilized in the creation of insulin producing bacteria. "Biotechnology is utilizing the sciences of biology, chemistry, physics, engineering, computers, and information technology to develop tools and products that hold great promise and concern" (Biotechnology Institute, 2005, p. 1). More specifically,

> "Biotechnology draws on the pure biological sciences (genetics, microbiology, animal cell culture, molecular biology, biochemistry, embryology, cell biology) and in many instances is also dependent on knowledge and methods from outside the sphere of biology (chemical engineering, bioprocess engineering, information technology, biorobotics). Conversely, modern biological sciences (including even concepts such as molecular ecology) are intimately entwined and dependent on the methods developed through biotechnology and what is commonly thought of as the life sciences industry.
> "Biotechnology has applications in four major industrial areas, including health care (medical), crop production and agriculture, non food (industrial) uses of crops and other products (e.g. biodegradable plastics, vegetable oil, biofuels), and environmental uses.
> "For example, one application of biotechnology is the directed use of organisms for the manufacture of organic products (examples include beer and milk products). Another example is using naturally present bacteria by the mining industry in bioleaching. Biotechnology is also used to recycle, treat waste, clean up sites contaminated by industrial activities (bioremediation), and also to produce biological weapons." (Anonymous, 2010a, p. 1)

Biotech offers attractive solutions for two reasons: biotech alternatives are as effective, or more effective, than conventional approaches and biotech alternatives are often less expensive than conventional approaches. This combination of cost and effectiveness factors often makes biotechnology a best value proposition by creating a "virtuous cycle" that delivers benefits to society and ecology through an array of consumer products. (Sunderland, 2009) In addition, this best value proposition is spurring collaboration among nations (Ray et al., 2009; Mugwagwa, 2009; Anonymous, 2010b)

Clean Brown

New approaches to mitigating pollution are being developed and implemented, but their long term effectiveness is controversial. Once polluted, the environment is notoriously difficult to clean. Critics allege that "pump and treat" pollution mitigation efforts are both expensive and temporary, since time has a way of eroding containment, making recontamination merely a question of time and degree (Gingrich, 2007).

In contrast, genetic engineering offers the future genuine pollution control, as super microbes can be developed to either digest the toxins, or otherwise neutralize them as stable precipitates (EPA, 2001). As recently witnessed in the Gulf of Mexico, natural bioremediation proved much more effective than other methods at removing oil from the water. Algae consumed the oil and excreted water and harmless gases back into the environment. Biotechnology companies have begun to isolate and farm these microorganisms as a crop:

> "Our Industrial Class Microbial Blends for bioremediation are extremely concentrated. These are specifically acclimated species of naturally occurring, non-pathogenic microbes. These microbial species are extremely effective for a very diverse range of hydrocarbon environmental pollution and contamination. They are designed specifically for remediation and bioremediation of hydrocarbon and oil spill waste. We custom blend up to 86 different strains of the highest quality microbes at a concentration of approximately 200 billion microbes per gallon or per gram with our products. Alabaster Bioremediation Corp. quality control ensures our customers of plenty of viable bioremediation microbes in a quality product that will work to bioremediate organic and hydrocarbon environmental pollution contaminants. ... Upon application onto an oil spill or pollution contaminated soil, the microbes will germinate and become active instantly. In good conditions these special microbial blends multiply exponentially within minutes. These begin the bioremediation to digest environmental pollution and wastes as long as all the necessary ingredients of water, oxygen and a food or waste source are present. Byproducts of their bioremediation degradation process are CO2, water, and trace amounts of organic salts. This is one of the many reasons we say we make 'The World's Best Bioremediation Materials'." (Alabaster Corp., 2010, p. 1)

Shrink Brown

One of the most important variables in shrinking waste is the quality of the raw materials. Much of the production process involves separating and purifying desirable compounds, and removing and disposing of the rest. However, biotechnology allows for customized crops, with a higher percentage of energy and other usable compounds, while minimizing unproductive waste products:

> "Industrial biotechnology applications have led to cleaner processes that produce less waste and use less energy and water in such industrial sectors as chemicals, pulp and paper, textiles, food, energy, and metals and minerals. For example, most laundry detergents produced in the United States contain biotechnology-based enzymes." (Biotechnology Industry Organization, 2010, p. 1)

In some cases reducing waste involves collecting and packaging byproducts as green alternative products, in and of themselves. For example, many towns recycle landscaping debris

such as leaf matter and grass clippings into organic compost, which is a valuable fertilizer. Composting recovered 22.1 million tons of waste nationwide in 2008 (EPA, 2009).

China is taking the lead in biogas conversion through a series of strategic alliances with General Electric. Massive plants are under construction to speed the conversion of animal manure into methane, which then can be burned to generate electricity (Runyon, 2008). Instead of having to dispose of hundreds of thousands of gallons of animal sewage, most of the effluent will be converted into power.

> "This biogas project will quickly pay for itself by meeting the customer's demand for cost-effective electricity and heat. We estimate that the customer will save more than US $1.2 million a year in electricity costs alone." (Jack Wen, president and CEO of GE Energy China, quoted in Runyon, 2008, par. 2)

Build Green

In terms of substituting green alternatives for conventional components or processes, biotechnology often offers virtual equivalents. The EPA identifies a variety of initiatives in these fields, all of which involve biotechnology:

- Green chemistry, also known as sustainable chemistry, is the design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances. Green chemistry applies across the life cycle of a chemical product, including its design, manufacture, and use.
- Green, or sustainable, building is the practice of creating and using healthier and more resource-efficient models of construction, renovation, operation, maintenance, and demolition.
- Green Suppliers Network works with large manufacturers to engage their small and medium-sized suppliers in low-cost technical reviews that focus on process improvement and waste minimization. (OPPT, 2010)

These initiatives are not confined to the federal level. For example, the State of California is working with industry to systematically identify and replace up to 80 thousand industrial chemicals with organic equivalents (Cone, 2008).

The Green revolution is perhaps most well established in agriculture, where a combination of genetic engineering, petrochemicals, and modern farming methods caused a boom in crop production (Tilman, 1998). However, these increasing plant yields have been slowing (Herrera-Estrella, 2008). Possibly one of the greatest challenges to be faced in the 21st century will be finding a way to feed, by the year 2050, an estimated global population of 9 billion people. Furthermore, as the population increases demand for diets richer in meat are projected to double global food demand in the same time period (Tilman, 1998). If crop production does not continue to increase, then there will not be enough food for the population, let alone the crops needed for alternative fuels or the production of basic compounds needed in myriad industrial processes. However, current agricultural production methods are often highly detrimental to the environment, requiring vast tracts of land and water (Berg, 2009). Moreover, the improper application of the chemical pesticides and fertilizers used in these methods results in significant losses in biodiversity, bioaccumulation of toxins within both the animal and human populations, eutrophication of surface waters, and pollution of ground water as well as causing increases in green house gases, smog, and ozone (Tilman et al., 2001). In short, the status quo is not sustainable, so the human population must utilize ecologically compatible strategies in

agriculture (Berg, 2009). Food production needs not only to increase a projected 50% but to do so using less land, water, labor, and chemicals (Khush, 2001).

Providing for the global population may largely depend on the human ability to create new plant varieties capable of growing in the environmental and climatic conditions encountered in the future (Herrera-Estrella, 2008). Biotechnology played a large part in the development of many new and better plant crop varieties possessing greater disease and pest resistance, higher drought and salt tolerance, and better nutritional value than their predecessors (Berg, 2009). These incremental improvements promise to continue to improve crop yields. With their proven success record these crops undoubtedly will help reduce the amount of land, water, fertilizers, and pesticides needed for future farmland. (Milne, 2010; Swackhamer, 2001)

Genetic modification is just the start -- there are several other methods of increasing crop yield involving biotechnology. One such method is the implementation of beneficial plant–microbe interactions in growing crops via microbial inoculants. Plant associated microorganisms have important ecological functions effecting overall plant growth and health, while enhancing their stress tolerance, disease resistance, and aiding in nutrient availability and uptake. These microbial inoculants can be used for bio control and plant growth promotion. As research continues these functions are likely to extend to include their acting as stress-protecting agents allowing for growth in areas previously unsuitable for occupancy due to salinity, heavy metal contamination, water logging, and other harsh conditions. Microbial inoculants unlike GMO's are a sustainable and environmentally friendly option that can be used in both conventional and organic agriculture worldwide. (Berg, 2009; Milne, 2010; Lewis, et al., 2010)

This piecemeal, incremental approach to sustainability is necessary. However, it is not sufficient to solve the earth's pressing ecological problems.

Grow Green

The radical potential of biotechnology is to create organisms to serve mankind that have never been seen before, a field called "synthetic" biology. For example:

> "At Synthetic Genomics, Dr. Venter wants to create living creatures — bacteria, algae or even plants — that are designed from the DNA up to carry out industrial tasks and displace the fuels and chemicals that are now made from fossil fuels. 'Designing and building synthetic cells will be the basis of a new industrial revolution,' Dr. Venter says. 'The goal is to replace the entire petrochemical industry'." (Pollack, 2010, p. BU1)

Beyond food, in today's world a variety of political, environmental, and geographic factors have lead to a worldwide search for alternative fuels, many of which come from crops. One of the more well-known examples is ethanol, which can be made from crops such as corn and sugar cane. While most alternative fuels are still in the process of large-scale commercial development the use of ethanol as a fuel is well established, despite its lower energy content. Brazil, for example, has made ethanol a commercially viable fuel through large scale production (Goldenburg, 2007).

One major argument against the large scale utilization of ethanol is that it is resource intensive, requiring too much land which could otherwise be devoted to food crops. This inadvertently leads to the destruction of habitat when more farms are built to compensate for the loss of cropland to ethanol production. However, whether or not this occurs depends largely on how the ethanol is produced. When native perennials are grown in degraded or abandoned farmland for biofuel production no ecosystems are compromised (Fargione et al., 2008).

Furthermore, production of ethanol from cellulosic materials, though not yet ready for large scale production, would prove land loss arguments moot because once the technology for such conversion is perfected all kinds of biomass would be available for use in the production of ethanol (Goldenberg, 2007). Examples of biomass which can be used in ethanol production include wood, feed stocks, and agricultural residues such as straw, cornhusks, and sugarcane (Goldenberg, 2007; Dawson and Boopathy, 2007). These residues would provide not only an inexpensive and readily available source for ethanol production but they also would take away no further farmland since these residues are created by farmland already in use and are often disposed of by post harvest agricultural burning. Such agricultural waste is created in large quantities throughout the world with the U.S. alone producing 1 kg of biomass for every kilogram of grain collected. Thus an excess of 40 billion tons of potential biomass is produced and destroyed each year. Studies have shown that fuel grade ethanol can be produced from agricultural wastes such as sugar cane. It is only a matter of time before the technique is feasible for larger scale production. (Dawson & Boopathy, 2007)

Beyond ethanol there are several other biofuel alternatives currently undergoing research and development. One prominent example is biofuel from algae.

> "In a laboratory where almost all the test tubes look green, the tools of modern biotechnology are being applied to lowly pond scum. Foreign genes are being spliced into algae and native genes are being tweaked. Different strains of algae are pitted against one another in survival-of-the-fittest contests in an effort to accelerate the evolution of fast-growing, hardy strains. The goal is nothing less than to create superalgae, highly efficient at converting sunlight and carbon dioxide into lipids and oils that can be sent to a refinery and made into diesel or jet fuel. 'We've probably engineered over 4,000 strains,' said Mike Mendez, a co-founder and vice president for technology at Sapphire Energy, the owner of the laboratory. 'My whole goal here at Sapphire is to domesticate algae, to make it a crop'." (Pollack, 2009, p. B1)

There are several benefits to using algae as a biofuel resource. They not only provide more fuel per farmed area of land than rapeseed, corn, or jatropha but also can be cultivated on land unsuitable for other forms of agriculture due to such factors as salinity (Gross, 2007). Furthermore, several avenues of this research are focused on utilizing wastewaters derived from local, industrial, and agricultural activities already in place thus providing a sustainable and cost effective method for cultivating biomass for biofuels. Thus, such activities as waste water treatment could provide a by-product capable of providing profit without consuming the fresh water or fertilizers required by other methods of commercial algal production (Park et al., 2010). The attractiveness of this option is further compounded by the fact that algal biomass does not compete with food crops for farmland and captures one pound of carbon dioxide for every pound grown and could potentially capture large amounts of carbon dioxide from the atmosphere (Subhadra and Edwards, 2010).

IMPLICATIONS AND SUMMARY

As more consumers are worried about climate change, faltering world economies, increasing prices, and dwindling supplies of natural resources, many consumers are choosing to make environmentally friendly choices a habit (Billitteri, 2008). Climbing oil prices and the peak oil environment will continue to drive demand for green alternatives (Hazell, 2009). Furthermore, consumers are demanding that governments take the steps needed to reduce global

warming (Langer, 2008). Corporations who become more sustainable are able to profit from new ideas, save costs, run more efficiently, sell more sustainable products, and satisfy a greater number of customers (Anderson & White, 2009). For example, computer companies have been taking incremental steps towards creating more energy efficient computers, incorporating recycled materials, and improving the energy efficiency of older systems through specialized software (Billitteri, 2008). Consumers are now searching for companies who are making green decisions on their own without the government requiring them to do so. Gladwin and Berdish (2010, p. 1) explain:

> "In an interdependent world confronting growing environmental scarcity and human deprivation, we will need business leaders who can create social value without increasing energy and material throughput; who can cope with the complexity of interconnected social, ecological, economic systems; who can adapt in the face of uncertainty; who can bring about global change through collaborative and disruptive innovation and who can master multiple alternative futures."

The need for the world's industrial companies to transform "from a dead end, eighteenth-century model into a new, sustainable model suitable for the twenty-first, may well be the greatest business opportunity that industry and entrepreneurs have ever seen" (Anderson & White, 2009, p. 212). Stayton goes on to explain how there is a definite need for new companies to enter the market who already have the knowledge needed to identify new ways to create innovative products from things which were once another person's trash (Perman, 2006). (Kolotilova & Netrusov, 2010; Koehler, 1996) As Price (2006, p. 1003) states, "Environmentalists are counting on entrepreneurs to produce a future green world." For example, women and immigrants have been instrumental in founding science-based biotechnology firms (McQuaid, et al., 2010). Environmentally focused entrepreneurs have an added advantage because they are able to differentiate their businesses and offerings from those companies who are choosing to simply ignore the environmentally sound buying habits of today's consumers. Some entrepreneurs are finding ways to take what was once considered a person's garbage and turn it into a profitable business venture (Perman, 2006). Due to these initiatives, green business continues to expand and venture capital firms are investing heavily. *Cleantech Capital Group* has predicted that from 2006-2009, $3.4 billion is being set forth in capital to fund green technologies (McCarthy, 2006). (Sardana & Scott-Kemmis, 2010)

However, given that total research and development investment in the United States is over $340 billion annually (NSB, 2008), green investment is little more than a drop in the bucket. Why are green initiatives treated as more of a market fad and fashion rather than a transformative trend? Because green initiatives are often cost intensive, and even cost prohibitive, in pollution intensive industries. Without biotechnology, going green is likely to remain relatively ineffective because only biotech advances hold the promise of developing green products and services that are genuinely competitive "best value" offerings, or in some cases, even cost efficient. Once this happens, green will become best practice, and markets and industries will be transformed.

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Figure 1: The Green Playing Field

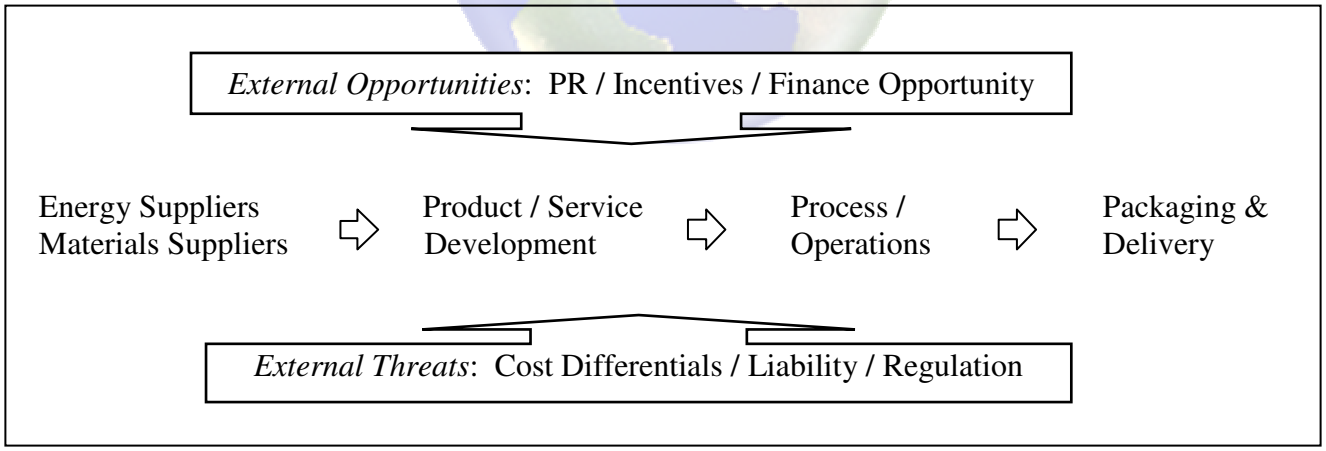

Figure 2: Competing Values Framework

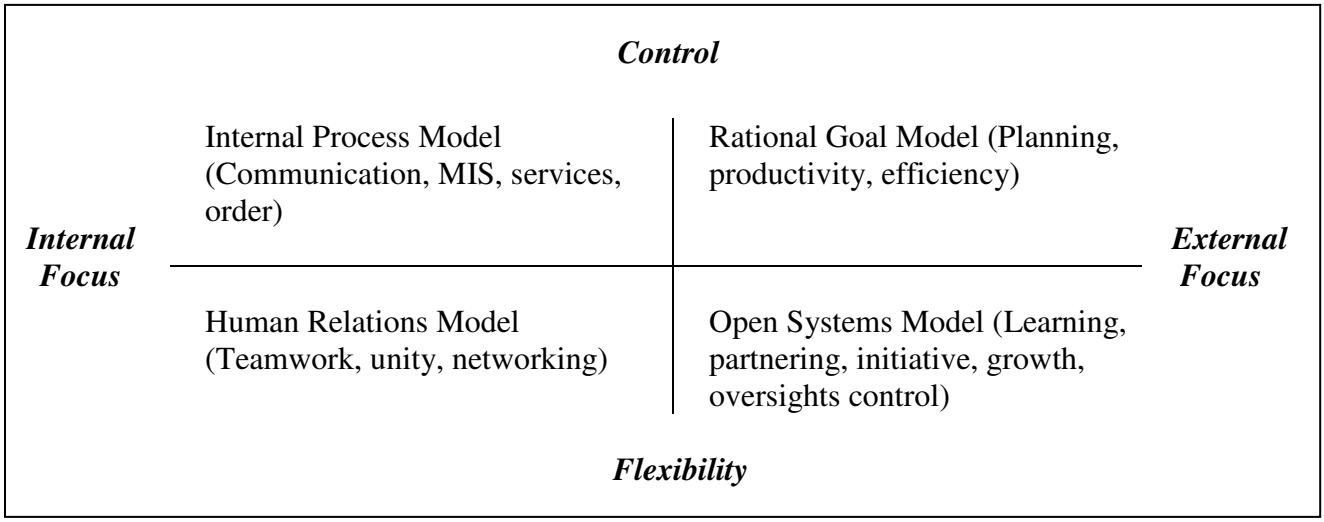

Figure 3: Green Initiatives