Ongoing Discussion "Thought Piece"

Thinking About Management from a Climate Change Perspective

Prepared by Andrew McKeon and Gipsie Ranney

Presented by

Andrew McKeon

amckeon@carbonrational.com

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Ongoing Discussion Host: Bill Bellows
william.bellows@rocket.com

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Andrew J. McKeon and Gipsie B. Ranney

In its Fall, 2009 issue, the MIT Sloan Management Review reported on a wide-ranging study in which 1500 business leaders were surveyed to ascertain their views on the new skills managers will need to address sustainability in the coming years. Results of interviews with experts in the field indicated that there were five management responsibilities that needed improvement: (1) the ability to act on a system-wide basis; (2) collaboration across conventional internal and external boundaries; (3) a business culture that rewards and encourages long-term thinking; (4) new capabilities in activity measurement, process redesign, financial modeling/reporting; and (5) new skills for engaging and communicating with external stakeholders. The survey results indicated that what is lacking in many sustainability initiatives is an overall plan. Efforts are often defensive and tactical rather than strategic; multiple initiatives are disconnected with one focusing on products, another on facilities, and perhaps others addressing employees, customers, or the general public. And sustainability initiatives as a whole reflect incremental rather than transformational change.

W. Edwards Deming spoke about transformational change. And even though he rarely used the term sustainability, Deming would have recognized his ideas reflected in each of the five areas that the Sloan Review cited: Deming taught (1) an appreciation for a system, (2) the importance of cooperation and collaboration as well as competition, (3) the need for managing for the long-term to foster a robust and durable enterprise, (4) new ways of looking at and understanding data and variation and the implications this has for management, and (5) an understanding of business in the broader context of community and society. The kinds of management approaches that sustainability experts today see as critical were being discussed – indeed urged – by Deming decades ago.

In 1980, American business discovered W. Edwards Deming and his work with Japanese industry. Although he was honored in Japan for his contribution to quality and the Japanese Economic Miracle and his American clients saw his potential here as raising the quality of U.S. products and services, his ideas went far beyond what was typically seen as the quality arena. Many of those deeper ideas about economic, physical and social well being got lost in the dust of the Total Quality Management (TQM) fad and other myopic readings of his work. Deming had much to say about survival and prosperity and the thinking and methods needed to sustain business enterprise and our economic well being.

In his last book, *The New Economics*, Deming outlined a way of seeing or lens for looking at work and at life. He called this lens The System of Profound Knowledge. It was to enable improvement of quality of management, quality of life, and quality of our interactions with one another and our environment. The System of Profound Knowledge was composed of four parts and their interactions. The four parts were:

- Appreciation for a system
- Psychology

- Knowledge about variation
- Theory of knowledge[1]

Today the issues facing business and society are more daunting than ever. From our viewpoint, our economic well being and our survival on this planet are currently at extreme risk. Global climate change threatens mankind by destabilizing the earth's climate and ecosystems within which human civilization has developed for the last 10,000 years. We cannot continue with business as usual and expect things to right themselves without any need for us to change. We recognize that the problems we are facing will not be solved by the kind of thinking that produced those problems. If there were ever a time when we need to think differently, it is now when survival is threatened. We believe Deming's ideas as expressed in The System of Profound Knowledge can help us positively transform our modes of thought and our approach to our relationships with the earth. In the following, we will discuss climate change, what we see as some of the important ideas from The System of Profound Knowledge, and different ways to look at the responsibilities and practices of management. We have organized the discussion in sections beginning first with a short discussion on climate change followed by ideas and approaches that can be used to address this challenge framed by the four parts of Profound Knowledge, realizing that these are not independent of one another.

Climate Change Primer

The climate change issue has been around much longer than most people realize. In the 19th century scientists began theorizing that burning coal could increase CO_2 in the earth's atmosphere and raise temperatures at the earth's surface. By the middle of the 20th century science began measuring significant increases in atmospheric CO_2 and attributing those increases to human industrialization. By the dawn of the 21st century an international panel of over 2000 climate scientists, the UN Intergovernmental Panel on Climate Change (IPCC), concluded that the earth was warming and that the warming was likely due to human-induced increases in atmospheric greenhouse gases, especially CO_2.

People reasonably pose questions about climate change, such as: Is a warming climate a problem? Won't some people benefit from warming? If humans are a part of nature, isn't human-induced climate change indeed natural? Should we bother doing anything about climate change? Is all the current buzz about climate change just a fad that will pass?

These questions are not invalid, yet call for a deeper understanding that climate change represents not just warming, but significant change in climate stability. Civilization resulted from agricultural surpluses that liberated humanity from subsistence living and enabled specialization. Today agriculture, water systems, and population centers depend on stability in climate and are threatened by its significant disruption. Human-induced climate change can trigger over a matter of decades to centuries dramatic switches in climate that might have taken centuries to millennia to unfold through natural variation.

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[1] Deming, W.E., *The New Economics, 2nd Ed.*, MIT Press, 1994.

The speed and magnitude of these human-induced changes threaten the very processes and components upon which humans depend. Some of these threats include:

- increased intensity of extreme weather events including floods, droughts and heat waves;
- threats to major sources of fresh water for billions of people;
- reduction in agricultural yields through crop migration and changes in soil moisture;
- damage to indigenous species of trees and flora;
- severe impacts on habitats of humans, animals and insects;
- loss of balance between components of irreplaceable ecosystems; and
- significant rise in sea-level from a destabilizing of the ice shelves in Greenland and West Antarctica.

Appreciation for a System

Climate change can be viewed as a problem, but also as a symptom – an indicator of a lack of alignment between two systems - the complex interactive system that is planet earth and the global economy embedded within it. Accordingly, addressing climate change requires an understanding of systems.

<u>Alignment and Optimization</u>
A system can be defined as a grouping of interrelated and interdependent components in the service of an aim. In human designed systems, the aim is, or ought to be, a mindful and explicit value judgment. In natural living systems, the aim is not spelled out as a conscious purpose but rather understood as a characteristic set of behaviors in response to physical and biological laws.

If the aim and workings of a system are unclear or opaque, then the system can not be optimized. In human systems a clear aim reflects values, enables constancy of purpose, and provides for collective and cooperative effort. In all systems it is important to understand the interrelationships and interdependencies in the system. The performance of a system with regard to its aims will be suboptimal if each part is optimized without an understanding of the interdependencies of all parts working together. Every component and sub-process within a system must be aligned with the aim and workings of the overall system. Lack of alignment to aim can lead to sub-optimization, decay, and the ultimate destruction of the system.

Our planet, with its living and non-living components, is an extremely complex and interdependent system. The aim, as elucidated by evolutionary theory, is resilience and sustainability, or to put it in other words, the continuation of life. While living systems have evolved to ultimately align with that aim, one very powerful system on earth – the global economy – has not.

As a system, the global economy has been a powerful determinant in the development of civilization. For millennia humanity has used effort, ingenuity and natural resources to further economic development and human advancement. With the onset of the Industrial

Revolution, humans leveraged mechanization and fossilized energy, bringing about sustained levels of growth and industrial progress never before seen in human history. Fossil fuels magnified both the power and the impact of human industry.

Climate change indicates that humanity has misunderstood the systems relationship between the earth and the global economy. We have been optimizing the global economy and believed earth's natural resources existed to serve that aim. While this has brought about great development and wealth, we are seeing other less beneficial consequences. The human economy is beginning to dominate the earth's capacity for renewal. We are seeing unprecedented ecosystem degradation and species loss, depletion of natural resources and now human-induced climate change, the most urgent and dangerous indicator that the old ways of thinking are unsustainable.

To optimize the overall system means we must understand the interconnections and interdependencies between the global economy and the earth as a system. If the old way of thinking saw the earth in service of the economy, a new way of thinking sees the economy in service of the earth – the economy as a subsystem of the earth to be aligned with and shaped by the characteristic behavior of natural living systems on the earth.

The key to addressing climate change is through an appreciation for a system – taking the complex interactive system that is the earth and aligning the global economy to its aim. This has huge implications for all aspects of human development, from how we procure and use energy, to how we design, manufacture and use goods, to how we feed ourselves. New management tools and new ways of thinking will be needed to manage this shift.

From Competition to Coopetition

No one company or country alone can address a problem like human-induced climate change. Global problems require cooperation in order to be solved, and climate change is the "perfect" global problem in that it has almost no localized effect. CO_2 generated in the U.S. on a Monday is by Friday impacting the atmosphere over Brasilia or Beijing as much as Boston. The system of concern is the planet, so to optimize the system and achieve industrialization without destabilizing the earth's climate will require the cooperation of all the world's countries, both industrialized and developing. International negotiations are expected to result in a binding global treaty on greenhouse gas emissions in 2010. The treaty will determine whether and how the nations of the world can cooperate to bring down and eventually eliminate anthropogenic emissions of CO_2 and other greenhouse gases while preserving the world's remaining natural carbon sinks such as the rainforests of Brazil and Indonesia. Without cooperation and trust between nations the climate crisis will not be addressed, creating unknowable consequences for humanity.

Global collaboration on the climate crisis is akin to the cooperation shown in other areas such as global time and calendar standards, or information and communications protocols. One of the most indispensable tools of business today, the internet, would not exist but for collaboration and standardization. Creating standards encourages innovation, business development and wealth creation. The explosive growth of the information technology sector over the last forty years can be attributed to "Moore's

Law" which established a standard of performance for integrated circuits around which an entire industry could organize itself. Standards for greenhouse gas emissions will be no different. Competitors who cooperate on the common problem of climate change and then compete once standards are agreed to can all benefit.

A new term in the business lexicon that refers to this is *coopetition*. Coopetition was originally defined as the act of competitors working together in areas where no relative advantage existed in order to share common costs. But the meaning is evolving to reflect more of what W. Edwards Deming once advocated: "cooperate on common problems; then compete."[2]

Deming also said, "Every example of cooperation is to the benefit of them that choose to cooperate."[3] This can clearly be seen by studying the signatories of the Kyoto Protocol. The Kyoto Protocol is an international agreement which took effect in 2005 imposing CO_2 emission reduction requirements on the industrialized nations in Europe as well as Japan, while transferring technology from the industrialized world to poorer countries to help them develop in sustainable ways. The U.S. never ratified the Kyoto Protocol fearing it would hurt our nation's competitiveness. Although we were once the world leaders in the development of solar and wind power technologies, today countries like Germany and China – both of whom are cooperating under Kyoto – have taken over as renewable energy juggernauts due almost entirely to Kyoto-based incentives. Their cooperation on climate change has brought a huge financial benefit and invaluable expertise, while the U.S. refusal (up to now) to participate in a global treaty on climate change has put us further behind. Almost certainly the nation that leads the world in clean renewable energy will be a global superpower in the 21st century. Lack of cooperation on climate change is hurting U.S. competitiveness, not protecting it.

<u>Rethinking Regulation</u>

There is an ancient African proverb 'If you want to go fast, go alone. If you want to go far, go together.' In addressing climate change we have to do both – go far fast. *Going fast alone* can mean encouraging small innovative companies to pursue new knowledge for the next big breakthrough in energy or sustainable technology. *Going far together* can mean laying the ground rules required of everyone, i.e., getting the policy right. If we want to go far in addressing climate change, and if we want to get there fast by enabling breakthrough technology, we can only do this with the right policy and the right regulation.

That regulation can spur innovation is becoming more evident. An example is incandescent bulb technology. A federal energy bill passed in 2007 mandated standards of efficiency beginning in 2012 that cannot be met by current incandescent technology. This is creating a wave of innovation to make incandescent bulbs more efficient. "There have been more incandescent innovations in the last three years than in the last two

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[2] Deming, W. Edwards, Lectures at Columbia University, Spring, 1991.
[3] Deming, W. Edwards, Lectures at Columbia University, Spring, 1991.

decades," according to Chris Calwell a researcher with Ecos Consulting.[4] All this innovation – greater efficiency and better lighting – is driven by new regulation.

Another powerful use of regulation to drive innovation is through pricing. Putting a price on an activity or practice that once was free is a way to change behaviors away from that practice. Emitting CO_2 into the atmosphere is still free, in terms of accounted cost, in the United States. That lack of regulation is stifling the innovation that would ensue were there a price on carbon emissions. Many business models for new innovative technologies depend on this price signal on carbon to make their alternative energy products viable in the near term in the marketplace.

Well thought out regulation can provide clarity and reduce uncertainty for corporate planning and investing. For example, electric utilities must make strategic decisions about how to generate the energy their customers will need twenty to thirty years into the future. It is very risky for power companies to make such long-term investment decisions in an unsure regulatory environment. That's why some utility-sector CEOs have been advocating for clear, consistent and reliable CO_2 emissions regulation. Companies need a price signal on carbon that only regulation can provide to make strategic decisions about the future. The sooner the U.S. Congress enacts robust, consistent and long-term greenhouse gas regulation, the better it will be for energy companies and the entire energy sector.

Interdependence and Aim

Curious people have always taken things apart in order to better understand how they work. Periods of great advancement in learning such as The Enlightenment saw everything from the motion of objects to the organs of animals being dissected, itemized and categorized – and new knowledge was born. Yet, as much as can be learned from breaking things into parts, much can be lost in overlooking the quintessentially important characteristic of systems – the connectedness and interdependence of their components and the emergent properties possessed by the system as a whole, but not by the parts.

System interdependence is the degree to which the action of each component affects and is affected by the actions of other components of the system. Degree of interdependence varies greatly from system to system. In viewing athletic teams as systems, both a bowling team and a basketball team exhibit interdependence – especially in terms of human social and psychological dynamics. But in terms of the operational aspects of the game, a bowling team is a much less interdependent system than a basketball team. If a bowling team aims to win, each player can align with that aim by trying to score as many pins as possible. If a basketball team aims to win, each player can not simply try to score as many baskets as possible. Instead players must understand each other's capabilities and styles, and work together in the dynamics of the game to take advantage of strengths and minimize weaknesses. In highly interdependent systems, optimized individual performance will in general produce sub-optimal system results. So while optimizing individual performance may work for a bowling team – it will not for a basketball team.

[4] Vestel, L.B., "Incandescent Bulbs Return to the Cutting Edge," *New York Times*, July 5, 2009.

The greater the interdependence within a system, the more important is the need for clarity of and alignment with system aim, and the more critical is the role of management. A great orchestral performance relies on the management of the interdependencies between individual performances, which is the critical job of the conductor. No symphony orchestra can perform at a high level without a great conductor, and neither can a business enterprise. In business the manager must orchestrate the interdependent roles, responsibilities, interests, behaviors, and attitudes of customers, suppliers, employees, shareholders, creditors, communities and governments in service of the overall aims of the enterprise.

For a complex interdependent system with multiple aims and considerations, how we weight these aims and considerations affects how we view system performance. For example, if the aim of an orchestra were not beautiful music but rather improved return on investment or reduced cost, then we might see the traditional way an orchestra is conducted as very wasteful. We might wonder why the French horn section is paid to do nothing while the cellists and oboists are kept busy – or wonder why the rest of the organization sits idle during long piano and violin solos. An orchestra is a highly inefficient system – but efficiency was never the aim. Efficiency and other issues such as revenues and costs are considerations in running any orchestra – but they are not the aim. The aim is the creation of beautiful music, with the conductor responsible for aligning the different individual performances in service of that aim. What seems wasteful or inefficient from the perspective of one aim may seem sensible or indeed necessary when viewed from another. And what may seem to make sense in the short-term – an efficient orchestra – may prove to be unsustainable in the long term since nobody wants to hear an efficient orchestra.

Much as the idle musician is out of alignment with the aim of an efficient orchestra, capping carbon emissions is out of alignment with the aim of a cheap energy economy. Capping carbon emissions can only serve to increase the cost of fossil fuels – clearly in conflict with maintaining low energy prices in the short-term. Yet scientists are warning with ever increasing urgency that human industry must stop emitting vast amounts of carbon dioxide into the atmosphere or else the earth's climate system may become unstable. If the more urgent aim for the global economic system is sustainability for the long-term rather than cheap energy in the short-term, then constraining carbon emissions is not only sensible, it is necessary and indeed urgent.

As every business enterprise is an interdependent system, it is also linked to the global economic system which in turn is embedded in a system of the greatest complexity and interdependence – the earth and its interacting atmosphere, hydrosphere, biosphere and geosphere. As the global economy has reshaped the natural world in service of its own aims, the impact on the natural world has been enormous. The record loss of species, the endangerment of ecosystems and the reconfiguration of the atmosphere are cause for concern in their own right, but in such a highly interdependent system they presage even greater consequences for the future. The most urgent example of these is an increasingly warming world as a consequence of greater CO_2 concentrations in the atmosphere. In optimizing the global economy, we may be sub-optimizing the earth.

Energy Security, National Security and Climate Security

"The earth is finite … fossil fuel reserves are finite … (we have) to invent ways of living off renewable energy sources … and to adjust our economy to the vast changes which we can expect from such a shift." So said Admiral Hyman Rickover of the United States Navy in a speech he gave entitled Energy Resources and Our Future on May 14, 1957. Unfortunately, American policy makers and industrialists have failed to heed this urgent message. Instead, cheap oil has been the energy policy of the U.S. government and of American industry for the last half century. This has led to a situation today where we import two-thirds of the oil we use. If America is to prosper in the 21st Century, energy policy must now be viewed in the context of a system. We must consider the full cost of dependency upon energy sources in unstable parts of the world that are rapidly decreasing in supply just as global demand is soaring.

Addressing climate change addresses energy security. Renewable forms of energy like solar and wind can be sourced from within the U.S., reducing the risk of dependence on hostile nations and governments for a resource with such critical national security implications. But beyond energy, even broader national security threats await America if we fail to address climate change. For the first time, the Pentagon and intelligence agencies are taking a serious look at the national security threats posed by climate change.[5] The military fears it will be increasingly called upon to deal with the humanitarian effects of violent storms, drought, mass migration and pandemics. Of even greater concern is the potential increase in the number of failed states due to climate stressed economies. These states tend to be breeding grounds for terrorist organizations and one failed state can destabilize an entire region. In appreciating climate change from a systems point of view, burning fossil fuel has hidden costs that are beyond measure.

In contrast to fossil fuels, renewable energy helps to align the global economic system with the earth and its climate system. Everything in the biosphere runs on renewable energy. More energy from the sun hits the earth's surface in an hour than the entire global economy can use in a year. Yet today the U.S. economy gets less than two percent of its energy from renewable resources. If the full cost of fossil fuels is taken into account, the cost to our energy security, our national security and our climate security, then the low-risk and low-impact solar and wind energy sources are comparatively cheap.

Seeing Business as a System

To make appropriate changes to businesses and economies that take interdependencies into account, it is necessary to see them as systems. A diagram showing the business as a system can better represent a business than the typical organization chart. In a way, the organization chart destroys appreciation for the system by failing to help people understand where they fit in the system and what their job is. It shows only the responsibilities of reporting, conveying the message that reporting upward is more important than getting the job done. A system diagram, on the other hand, can be used as a way for employees to recognize who their upstream suppliers and downstream customers are.

[5] Broder, John, "Climate Change Seen as Threat to National Security" *New York Times*, August 8, 2009.

Flowcharting can also be a powerful tool in addressing climate change and achieving sustainability. Creating a flow chart for a product realization process (or service realization process) can help management see where the interactions are with the external environment, see the “carbon footprint” – CO_2 inputs and outputs, and see how the business flow aligns (or is misaligned) with the ecosystem. For example, a process flow can indicate not only where the CO_2 and other greenhouse gases are generated in the process, but where there is waste being discarded to the environment or where there are processes generally not aligned with the overall ecosystem. Flowcharting can prompt new ways of thinking to reduce, eliminate or replace these processes with others that are aligned and thus become restorative to the overall system.

<u>Considering Delayed Effects of Actions</u>

Currently, we see the delayed effects of past actions. These effects include ongoing difficulties in the Middle East, unpredictable fluctuations in energy prices, degradation of the environment, and climate change. Lack of attention to potential future effects of actions we take can lead to devastating consequences.

The consequences of climate change lie in the future but the costs to address them – both financial and political – must be borne in the present. Changes by management to address climate change may not take effect for months or even years. The immediate effect may be negative to the bottom line. But management needs to be guided by consideration of potential future losses as much as by the next quarter’s numbers if they wish the company to survive and prosper. The leading companies in the 21st century will likely be sustainable enterprises aligned with the workings of the biosphere. The founder of Interface Carpet Company, Ray Anderson, was guided by such considerations.[6] Anderson transformed his organization by aligning it to the principles of living systems. Interface now designs industrial carpet by studying such things as how a rainforest builds a forest floor. Interface’s vision is to sell every carpet it makes and then reclaim it at the end of its useful life, peel it apart and reuse every component in making the next new carpet. This process is called ‘closed loop’ recycling. And customers have responded enthusiastically. At Interface, looking to nature as a model brought innovation, reduced waste, reduced costs, reduced greenhouse gas emissions, new markets, and an involved and highly motivated workforce.

Building a sustainable enterprise requires the active participation of management at all levels. The first step is for executives to accept their joint responsibility to learn about sustainability. The move to name a Chief Sustainability Officer does not relieve members of upper management of their responsibility to understand the issue and to develop appropriate methods to address it. If a Chief Sustainability Officer is appointed, their responsibility should be to coordinate initiatives across functional areas, not to accept the responsibility for other members of management. The second step is to identify where greenhouse gases are generated in the system, where waste is being discarded to the environment, how that waste could be eliminated or transformed into a usable form, where energy is wasted, and where it can be used more efficiently. The

[6] Anderson, Ray, *Mid-Course Correction*, The Peregrinzilla Press, 1998.

third step is to engage the entire organization in inventing new, sustainable ways to produce products and services.

Toyota Motor Corporation has also used thinking that is consistent with the principles of living systems. The biosphere is an interdependent, self-organizing system of seemingly infinite diversity and Toyota reflects these characteristics in organizing its work to produce low cost products in variety on a made-to-order basis.[7] While neither Toyota nor any other manufacturer of fossil fuel powered automobiles can be considered a truly sustainable enterprise, the thinking that informed Toyota's efforts at managing work can be taken further and applied to make the types of products in the future that do align to the natural environment.

In addressing climate change there is opportunity for management to find immediate positive results. Energy efficiency provides opportunities for instant cost savings. A 2007 study by McKinsey & Company reported that forty percent of the reductions in greenhouse gases needed to significantly de-carbonize the global economy – and help stabilize the earth's climate system – can be done at a negative cost.[8] However, other actions needed to transform an organization into a sustainable enterprise, such as changes in design, procurement, manufacturing, transport, and disposal – all directed by management – have higher upfront costs and delayed returns. But such a transformation is going to be essential for successful companies in the 21st century.

<u>Understanding Employee Goodwill</u>

Companies are finding today that when they choose to address issues like climate change and sustainability it attracts a great deal of employee interest. IBM has a global sustainability program which was started by individual employees concerned with making their workplace more environmentally sound. In one plant in Ireland nearly 200 employees volunteered to look at ways their company could reduce waste, reduce greenhouse gas emissions and otherwise be more efficient and thus less environmentally damaging.

Management should always provide a clear understanding of the organizational aim and system flow to enable individual workers to know what their job is, how their job fits in with the work of others and how it contributes to the aim of the system. When this is related to sustainability and addressing climate change it transcends the usual business priorities, and there is an abundance of goodwill in employees that can be tapped. As an organizational aim, addressing climate change seems to be more personal, connecting workers' jobs to their lives outside work including their families and children. Individual workers are thus able to engage not just their labor but their hearts and minds, and thus understand what it means to do a good job, feel fulfillment and take joy in work.

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[7] Johnson, H. Thomas, *Profit Beyond Measure* , The Free Press, 2000

[8] "Reducing Greenhouse Gas Emissions – How Much at What Cost," McKinsey & Co., December, 2007.

Recognizing Information Intensity and Energy Efficiency

Ramon Margalef, the great Spanish ecologist, once said that an ecosystem can be thought of as a physical system that transmits and stores both energy and information.[9] In general, nature rewards resource conservation. As ecosystems develop and mature they go from being resource hungry and energy intense to becoming resource conserving and information intense.

Human economic development appears to be progressing very differently. In the 200 years since the dawn of the industrial revolution, the global economy has been on an increasingly energy intensive path. The technological society of today is four to five times as energy intense as early industrial societies, and 100 times as energy intense as advanced agricultural societies.[10] Such energy intensity is sustainable neither from the point of view of fossil fuel supply nor from the perspective of its climate impact.

In order to create a more sustainable economy, humanity can study our living planet as a system to provide direction and instruction. Janine Benyus writes in *Biomimicry* that nature runs on sunlight, uses only the energy it needs, fits form to function, recycles, rewards cooperation and diversity, curbs excesses, and taps the power of limits.[11] The earth's ecosystem has developed to become a very information intense system. E.O. Wilson, one of the world's foremost biologists, pointed out that one strand of one chromosome of a domestic mouse has more information content than an entire set of encyclopedias. Biological systems use this information intensity to make efficient use of energy through self-regulation and self-monitoring. As an ecosystem develops, information intensity increases as energy intensity decreases. Robert L. Olson once wrote, "It is information processing, the vast majority not of a 'conscious' type, that has made the biosphere's self-regulation and evolution possible."[12]

Perhaps this is the model for global economic development: using information as a key to resource conservation; i.e., creating a more information intense and more energy efficient system that emulates the biosphere from which it emanates. But another key to biological systems is that information is embedded in the systems themselves, not carried in separate vestigial structures that are in constant need of updating. Biological systems carry their information with them and use it in the context of and as a part of their development. Information is not kept in separate storage.

Managing the Organization's Work

The idea of properly managing energy and information applies also to the everyday work of an organization. The mental and physical energy of the people of the organization can either be wasted or used for innovation and improvement. How well information is managed – guarded and controlled or made available and accessible – can also affect organizational performance.

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[9] Margalef, Ramon, *Perspectives in Ecological Theory*, University of Chicago Press, 1968.
[10] Cook, E., "The Flow of Energy in an Industrial Society," *Scientific American*, 1971, p. 135.
[11] Benyus, Janine, *Biomimicry*, Harper Collins, 1997
[12] Olson, Robert L., "Nature's Advanced Technology," *Humankind Advancing*, Vol.3, No.4, October, 1992.

When systems of review and reward generate competition between individuals and groups or functions in an organization, energy is spent competing rather than developing new ideas and better methods. When employees are forced to attribute variations in results to specific causes when they are a function of the noise within the system, this wastes energy and propagates further waste. When information and communication systems contain unnecessary redundancy and overlap, energy is wasted in repetitious activity and attempts to resolve confusion. An example is the American healthcare system. Because of the lack of electronic medical records and the lack of commonality of reporting requirements by different insurance providers, there is tremendous waste of human labor and cost. Waste occurs when internal customer-supplier relationships are not recognized and improved. Further waste occurs when purchasing decisions are made on the basis of price without consideration of cost of use. Even more waste and cost occurs when the needs of customers are ignored.

Seeing the organization itself as a system and managing it to effectively use its resources has great potential payback in any business environment, but in an age of human-induced climate change it is an urgent necessity.

Psychology

History is replete with examples of ideas and theories that once were widely accepted and then were overturned. Galileo's work on the sun-centered system earned him house arrest in the latter part of his life, but ultimately the theory of an earth-centered system was abandoned. Pre-Darwin Western thinking viewed the biosphere as humanity's own stockroom – a static unchanging place we owned and could use as we wished with few or no consequences. After Darwin's ideas were widely accepted, scientists began viewing the biosphere as a dynamic and changing system – something we didn't own but rather were part of and to which we owed our continued existence. Human-induced climate change makes our interdependence with the biosphere even clearer.

<u>Re-examination of Assumptions and Roles</u>

We make use of cognitive and inferential tools to interpret the world. Those tools are powerful, but subject to error. MIT Sloan School Professor Edgar Schein wrote of organizational culture as basic assumptions that have appeared to work well enough to be considered valid and so are taken for granted and tend to drop below the level of awareness.[13] Those assumptions are then used to interpret the world and to deal with the external environment. When the environment changes and the organization's assumptions do not, the organization is at great risk. An understanding of the need to continually examine and re-examine our assumptions about the nature of reality improves our abilities to deal effectively with the world.

There are two contexts in which the employees of an organization have an effect on climate change. The first is in their lives outside the organization. The second is their contribution to the organization's efforts to address climate change. It is assumed here

[13] Schein, Edgar H., *Organizational Culture and Leadership*, Jossey-Bass, 1990.

that the organization will work to educate employees about climate change and the obligations the organization and they as individuals have to ensure a viable future. Provision of information and education are necessary, but not sufficient, to unlock the abilities employees may have to contribute to the organization's efforts. Psychology has much to offer the organization in its efforts to unlock those abilities.

In *The Human Side of Enterprise*, MIT professor Douglas McGregor identified what he called Theory X: "The traditional view of direction and control." He identified three basic assumptions about human nature and behavior that underpin Theory X: "1. The average human being has an inherent dislike of work and will avoid it if he can….2. Because of this human characteristic of dislike of work, most people must be coerced, controlled, directed, threatened with punishment to get them to put forth adequate effort toward the achievement of organizational objectives….3. The average human being prefers to be directed, wishes to avoid responsibility, has relatively little ambition, wants security above all."[14] McGregor proposed Theory Y, based on very different and far more positive assumptions about the nature of people. Deming adopted a positive view of people as well. In his book, *The New Economics*, Deming wrote about the role of a manager of people. Deming asserted that a manager of people "understands that people are different from each other. He tries to create for everybody interest and challenge, and joy in work…" He also stated that the manager of people "understands the interaction between people and the circumstances that they work in." The manager of people "creates trust. He creates an environment that encourages freedom and innovation…"[15]

<u>Management of People</u>

Nearly fifty years ago, Harvard psychologist Chris Argyris wrote of the "psychological contract," unwritten expectations of the employer and the employee.[16] According to Argyris, the employer's expectations included loyalty and commitment to the organization. The employee's expectations included a sense of dignity and worth, fair treatment, and opportunities to learn and grow. Psychologists have reported on breaches of the psychological contract that include failure to provide career guidance and mentoring, poorly defined job responsibilities, lack of resources to perform the job, and lack of recognition of accomplishments.

Many psychologists have written about employees' perceptions of fairness in the workplace. One area in which employees make judgments of fairness is in distribution of resources and pay. Employees may have different criteria for distribution of resources and pay, depending on the context. When the context is non-threatening, employees tend to think that reward should be commensurate with effort, as they perceive it. These perceptions usually don't take context into account appropriately. The effects of management and other components of the system tend to be ignored. When the situation is threatening – for example, when the organization announces layoffs – employees may adopt a more humane viewpoint and tend to believe that it is more fair for employees

[14] McGregor, Douglas, *The Human Side of Enterprise: Annotated Edition*, McGraw-Hill, 2006.
[15] Deming, W. Edwards, *The New Economics*, 2nd Ed., MIT Press, 1994.
[16] Argyris, C., *Understanding Organizational Behavior*, Dorsey Press, 1960.

who are younger and do not have dependents to be laid off before older workers who will have difficulty finding another job.

Employees also judge the fairness of processes used to make decisions and the adequacy and honesty of explanations that are provided for those decisions. The respect and courtesy shown to employees also affects their perceptions of fairness. Employee perceptions of fairness can strongly affect their attitudes and willingness to contribute to the organization's efforts. The human resources function in an organization has an opportunity to contribute to organizational performance in all areas by ensuring that managers at all levels are thoroughly educated regarding appropriate ways to manage people, as well as ensuring that managers understand their role as models.

There are other opportunities for improvement of organizational performance by examining the organization's systems. Organizational policies and rules can communicate lack of trust, offend the dignity of employees, and generate cynicism in the organization. Reward systems that create destructive competition and negative interactions, rather than collaboration, between individuals and groups can subtract from the organization's ability to deal effectively with the external world. The ability of employees to trust each other and their managers affects their willingness to freely exchange knowledge and information that may affect the quantity and quality of innovative ideas. Undoubtedly, an organization's efforts to deal with climate change will require organizational change. The discipline of psychology has much to say about effective and ineffective approaches to change.

A connection can be made between appreciation for a system and the effective use of psychology in the workplace. Each member of the human species is a system; he or she is not two systems: a work system and an outside of work system. What happens to the individual in the workplace affects his or her attitudes and behavior toward his or her family, neighborhood, and larger community. Damaging employees' sense of dignity and worth may have strong negative effects outside the workplace. Giving the employee opportunities for growth and challenge in the workplace may equip the employee to make larger positive contributions outside the workplace.

Deming knew that transformation could not take place without driving fear out of the organization. By fear, Deming was not referring to that which comes from a physical threat – such as the one presented by climate change. He was referring to the fear within the workplace that saps people of energy, takes their focus away from the organizational aim, damages cooperation and constancy of purpose, and leaves people thinking about their own self-preservation. Driving out fear and building trust can unlock the creative potential that will lead to innovation and sustainability.

As climate change transforms the human systems that are corporations, psychology will play a key role in determining whether and how these corporations succeed. Given the mountains of scientific evidence, the decades of peer-reviewed vetting, and the magnitude of the threat posed, one may question why American society has not acted sooner and more swiftly. The answer is, in part, bound up in human psychology.

Understanding the psychology of individuals and groups and putting that understanding to work can improve the lives of people and the effectiveness of organizations. On a larger scale, an understanding of psychology can help to design approaches that will help society at large become more knowledgeable of the effects of climate change and the human population's role in acting to prevent further damage to the biosphere.

Knowledge about Variation

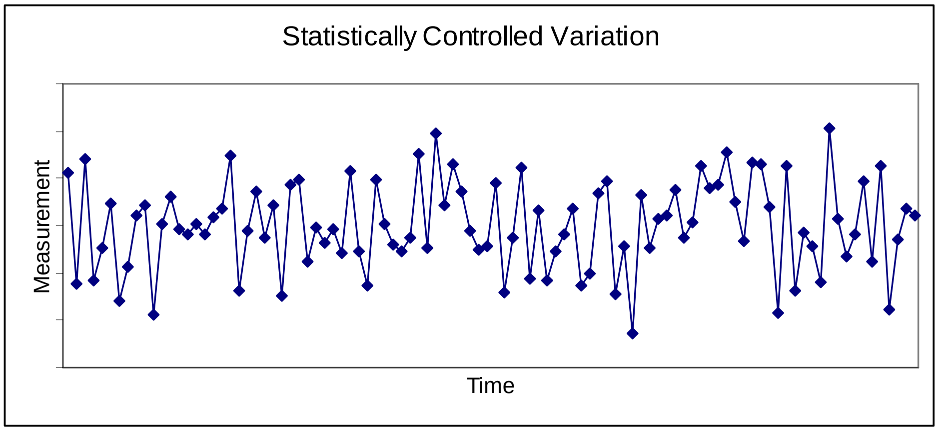
The high temperature in Manhattan varies from day to day, as does the number of traffic accidents in Los Angeles, the number of deaths in Dallas, and the number of births in Chicago. Likewise, revenue from sales of products or services, expenses for electricity, costs for warranty, legal expenses, and direct labor costs vary from month to month. Measured amounts of carbon dioxide and other greenhouse gases in the atmosphere, surface temperatures on land and in the ocean, number of hurricanes, number of tornadoes and other climatic indicators vary from year to year. We are surrounded by variation. Since this is the case, how do we make sense of the numbers that come our way? What do the fluctuations in the numbers mean? Do we ascribe too much meaning or too little to the fluctuations? Can we use the numbers to predict with a high degree of belief what the future holds? What kinds of actions should we take to change the future? These kinds of questions have importance to managers of business and to inhabitants of the earth. Some understanding of variation can be helpful to answer those questions.

<u>Interpreting the Meaning of Variation</u>
Walter Shewhart, a physicist at Bell Labs, provided a way to look at variation that can be very helpful in interpreting the meaning of variation in series of numbers. His aim was to use the messages in variation as a guide to better actions in management of business processes and better use of data in prediction. Although his focus was economic control of quality in manufacturing, his ideas can be applied in other contexts. Deming applied Shewhart's ideas to business organizations in general, speaking in particular to managerial thought and action.

Shewhart and Deming used a particular concept to look at variation in series of numbers. That concept was statistical control. The concept of statistical control and the use of some simple tools to analyze series of numbers enabled them to make judgments about the causes of variation in series of numbers and thus avoid the mistakes and waste associated with misinterpretation of variation and misidentification of causes of that variation. Figure 1 is an attempt to illustrate the concept of statistically controlled variation.

Statistically controlled variation in any series of results or measurements shows no discernible patterns, the results vary around the same average over time, and the degree of variation stays about the same. Variation of this kind is referred to in some disciplines as "white noise." When a series shows statistically controlled variation, it makes no sense to try to find specific reasons, or causes, for the individual up and down fluctuations in the series. Shewhart called the causes of statistically controlled variation "chance" causes; Deming referred to those causes as "common." The general idea was

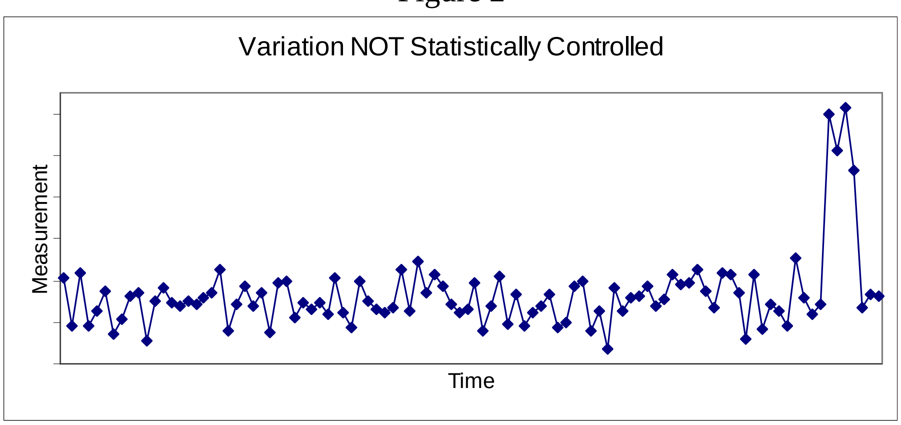
Figure 1



that the fluctuations – the variation – were produced by a set of causes that were always acting on the results and whose effects combined to produce noise. Common causes were built into the system that produced the results. If nothing were done to the system that affected the causes of variation, then future results would look the same: they would exhibit the same behavior as past results. In many cases, the variation in white noise might be greater than desired. If that were the case, a reduction in variation would be accomplished by using various methods to identify sources of variation that take into account the structure and dynamics of the system and act appropriately on those sources.

Figure 2 shows variation that is not statistically controlled. It would be natural to ask what affected the four points near the right-hand side of the graph that are noticeably different from the others. The first question would be, "What happened?" The next would be, "What caused that?" Shewhart took unusual data points such as the ones shown in the graph as signals of what he called "assignable causes." Deming used the term "special" causes. Since the scale on which data are plotted can influence the picture of the variation, Shewhart developed a method to identify signals of special cause called the statistical control chart. Statistical theory provided a means to define how much variation of what kind would exist in a collection of data when only common (chance)

Figure 2



causes were affecting the results. Variation in excess of that amount or unusual patterns in the data provided signals of special causes.

Patterns in Variation

Variation that shows a clear pattern that is not noise is also not statistically controlled, but this type of variation can sometimes be modeled and theories can be constructed about the causes of the pattern. The variation in Figure 3 is clearly not statistically controlled. The numbers are monthly figures for U.S. Balance of Trade.

It would be relatively easy to use statistical methods to establish a model for the data. It is common practice to do this with data such as that shown in Figure 3. The model is then used to make predictions of future results. Since this amounts to extrapolation beyond the time range of the data available, predictions such as this are subject to uncertainty beyond what statistical theory would indicate. In such a case, knowledge of the subject matter is required to have any substantial degree of belief that the prediction will be accurate. In the picture shown in Figure 3, any statistically-based prediction would indicate that balance of trade figures would continue to grow more negative.

Figure 3

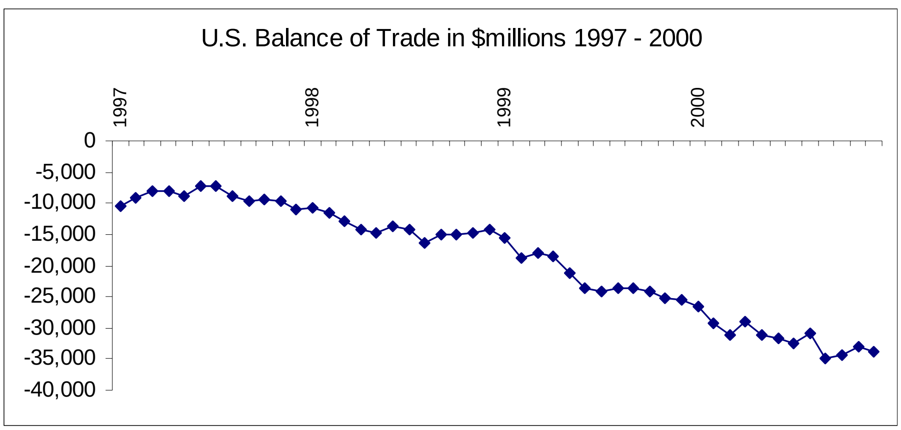
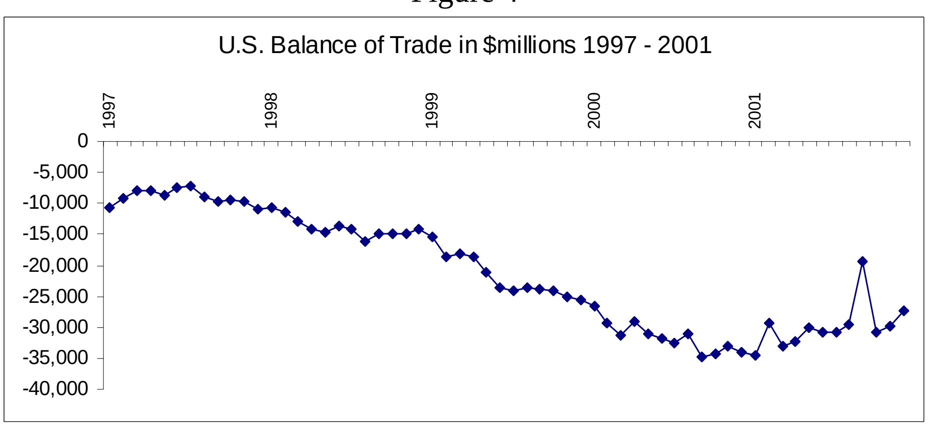


Figure 4 shows what actually happened in 2001. In addition to a general upturn in the

Figure 4



figures, there is a signal of a special cause: a consequence of 9/11. If there is no subject matter knowledge to explain the pattern of behavior in a series of results that does not exhibit statistical control, then predictions of the future based on the past are subject to great uncertainty. Additionally, rare events can occur.

Figure 5

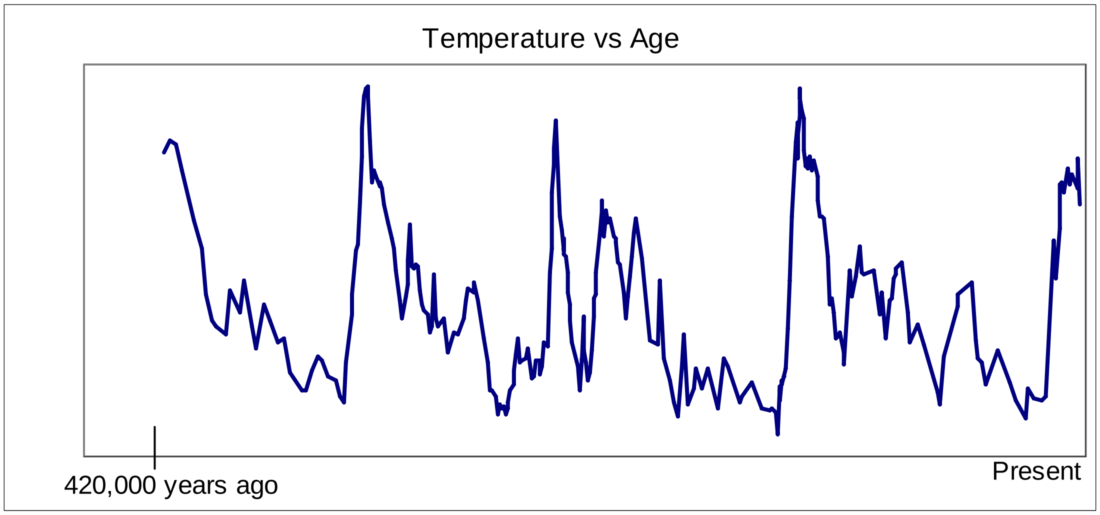
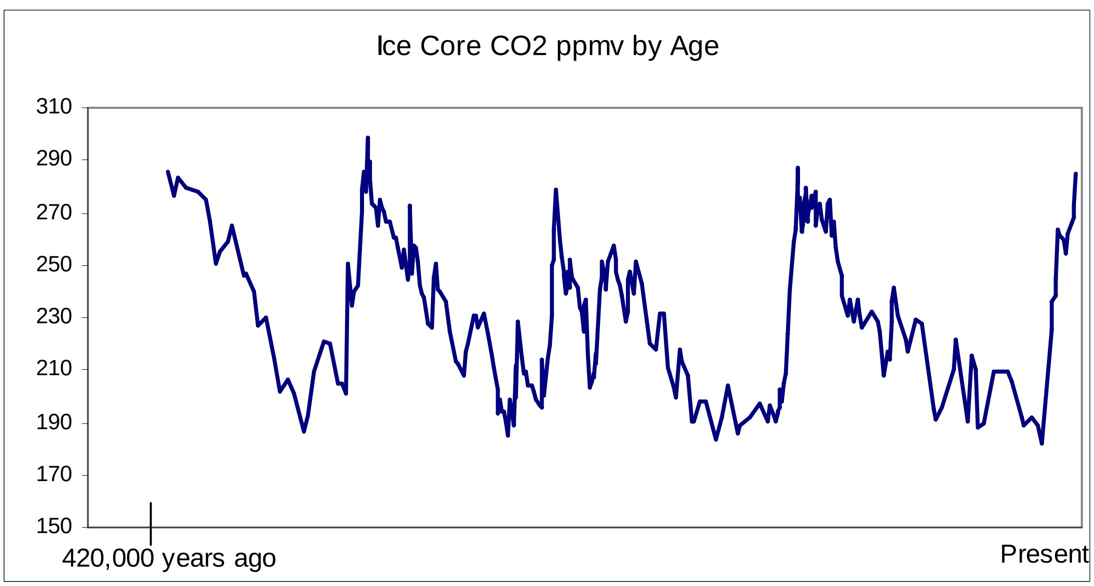


Figure 6



From Petit, J.R. et al, 2001, Vostok Ice Core Data for 420,000 years, IGBP PAGES/ World Data Center for Paleoclimatology Data Contribution Series #2001-076. NOAA/NGDC Paleoclimatology Program, Boulder, CO, USA
obtained from ftp.ncdc.noaa.gov/pub/data/paleo/icecore/antartica/vostok

There are cases in which widely held theories exist to explain patterns of behavior in series of results. Of course, predictions of the future are still conditional: "IF the cause system remains as it was, this is what can be expected." Figures 5 and 6 show data from ice cores obtained in Antarctica. Figure 5 shows fluctuations in temperature over a period of roughly four hundred thousand years. Figure 6 shows measurements of carbon dioxide in parts per million. Clearly, these two series are not simply white noise. They both show a clear cyclical or periodic pattern. Further, the pattern is very similar for the two series; the series exhibit correlation. Both of these series illustrate variability in climate over four hundred thousand years. Scientists relate the periodic behavior to the Milankovitch cycles which are governed by the precession, obliquity, and eccentricity of the Earth's orbit.[17] The amplitude of the fluctuations in temperature over the period of the ice core data is greater than would be expected from orbital effects alone. One explanation for the increased amplitude is that factors within the climate system interact dynamically with one another to increase the fluctuations in temperature. When temperature warms due to orbital changes, carbon dioxide levels in the atmosphere rise. One explanation for this is that as atmospheric temperatures rise, ocean water temperatures rise, and warmer ocean water holds less carbon dioxide so that atmospheric carbon dioxide rises as well. The dynamics of the situation are explained as a reinforcing feedback loop. Understanding of the earth's climate as a system helps to explain the variation. However, atmospheric carbon dioxide levels are now approaching values that are thirty percent higher than the highest values seen in the ice core history. Predictions of atmospheric carbon dioxide levels based on the ice core data and theories explaining them would never result in predictions of atmospheric carbon dioxide levels as high as they have been recently. This appears to indicate that something else besides periodic variation predictable by Milankovitch cycles and the dynamics of climate is present in the recent past.

The graphs in Figure 7 show recent history of global temperature and carbon dioxide levels.[18] These graphs show a lack of statistical control for a much shorter time span than before. One notable aspect of the carbon dioxide graph is that the <u>rate</u> of increase in the figures appears to increase beginning about 1960. Again, there is correlation between the two kinds of measurements. Some of that correlation can be explained by the same positive feedback mechanism mentioned earlier. However, "analysis of isotopes, which can distinguish among sources of emissions, demonstrates that the majority of the increase in carbon dioxide comes from combustion of fossil fuels (coal, oil and natural gas)."[19]

The increase in carbon dioxide then contributes to what is called the 'enhanced' greenhouse effect, the result of large scale burning of fossil fuels, leading to global warming beyond what would be expected to occur naturally. The natural greenhouse effect has long been understood. "The greenhouse effect refers to circumstances where the short wavelengths of visible light from the sun pass through a transparent medium

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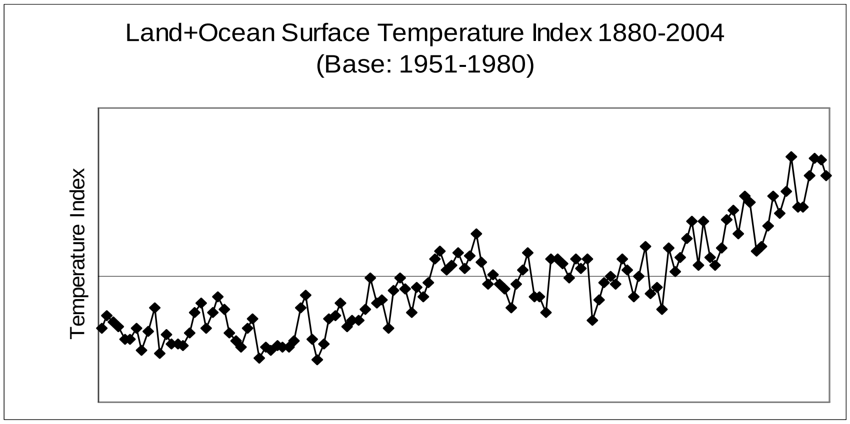
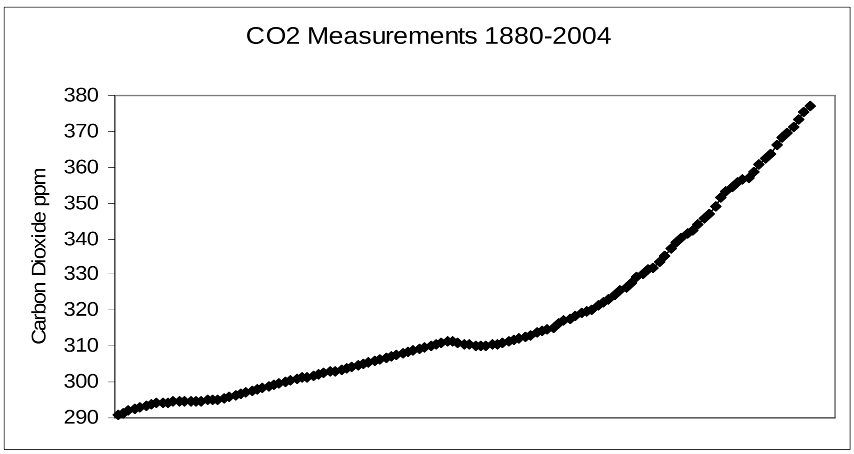
[17] Precession is change in direction of the earth's axis of rotation; obliquity is the inclination angle of the earth's rotation axis in relation to its orbital plane; eccentricity refers to how much the earth's orbit deviates from a circle – eccentricity changes as a result of gravitational attractions among the planets.
[18] Source for Temperature Index Data: http://data.giss.nasa.gov/gistemp/graphs/Fig.A2.txt. Source for CO2 Figures: GHGs.1850-2004_GISS2004
[19] Collins et al (2007), "The Physical Science behind Climate Change," *Scientific American*, 297(2), 64-71.

Figure 7





and are absorbed, but the longer wavelengths of the infrared re-radiation from the heated objects are unable to pass through that medium. The trapping of the long wavelength radiation leads to more heating and a higher resultant temperature. Besides the heating of an automobile by sunlight through the windshield and the namesake example of heating the greenhouse by sunlight passing through sealed, transparent windows, the greenhouse effect has been widely used to describe the trapping of excess heat by the rising concentration of carbon dioxide in the atmosphere." [20] This is known as the enhanced greenhouse effect since human activity and the resultant increase in concentrations of atmospheric CO_2 have enhanced the natural greenhouse effect, with greater concentration of carbon dioxide allowing less heat to escape into space.

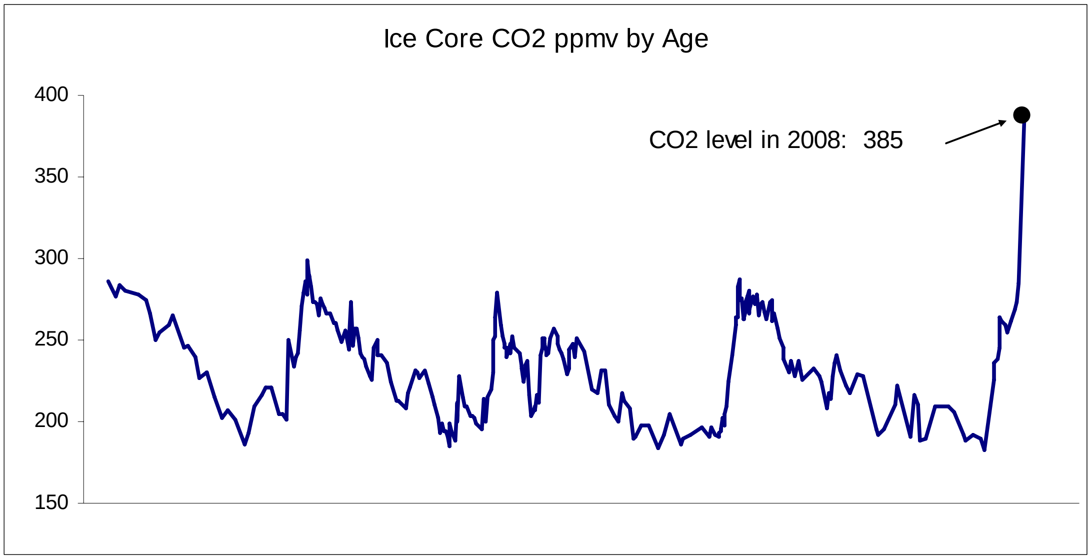
Figure 8 is the same as Figure 6 except one point has been added. The additional point is the level of carbon dioxide recorded in 2008. It is clear from this picture that there has been a change that would not have been predictable from hundreds of thousands of years of earth's history. One rational explanation appears in the previous discussion.

Deming often said "Management is prediction." Today scientists are predicting that unless human industry radically changes course from business-as-usual, the concentration

[20] http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/heat

of CO_2 in the earth's atmosphere will be higher by mid-century than it has been in over fifty million years – a time when the earth's climate was very different and much hotter. Is there a role for the management of a business enterprise in addressing the uncertainties associated with this apparent long-term trend? Is the role to mitigate against such an eventuality? To adapt to it? Or perhaps some combination?

Figure 8

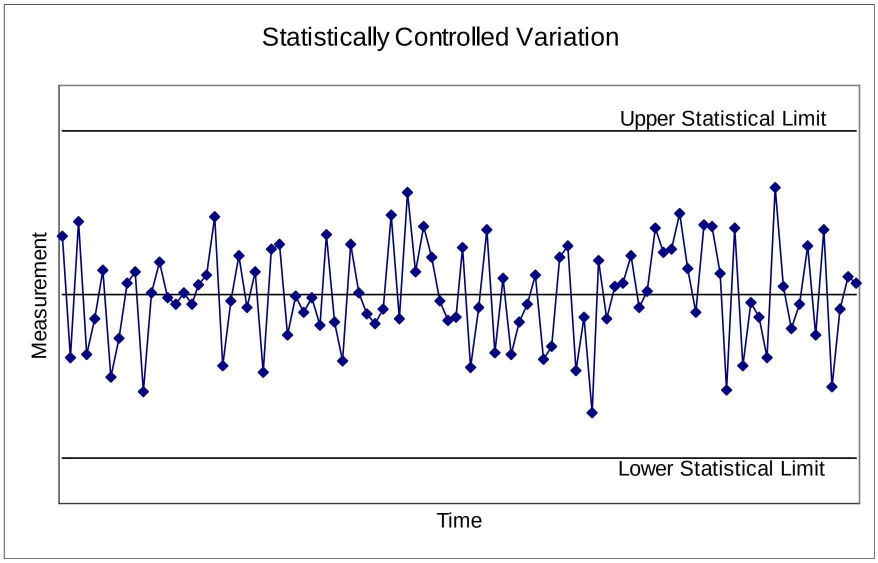


Using Knowledge about Variation in Management

Knowledge about variation has contributed to understanding of the earth's climate and it can also contribute to management of a business enterprise. Although Shewhart's methods have been applied often at lower levels in organizations as tools to manage and improve individual production and service processes, their potential for benefit may be orders of magnitude greater when applied at executive levels of business organizations. Interpretation of variation using Shewhart's methods can guide actions aimed at improvement of business performance. One benefit is reduction of enormous waste and complexity brought about by incorrectly reacting to variation.

Figure 9 shows a statistical control chart constructed from the data described earlier as "white noise," that is, statistically controlled variation. The upper and lower statistical limits define the limits of common cause variation that could be produced by the system that produced these data. Since there are no points outside these limits and no discernible patterns in the data, the variation is judged to be statistically controlled. The conclusion is that this is the variation that the system produces and, as long as no change is made to the system, the future will look like the past: future results will vary within these same statistical limits. The statistical limits define the variation the system is capable of producing. If a result beyond the statistical limits is desired, an appropriate change will have to be made to the system. The system includes the people who work in it; generally, people who work in the system do not have the authority to make significant changes to the system. Setting numerical goals or targets outside the boundaries of the system's

Figure 9



capabilities and expecting people who work in the system to reach those targets without any changes to the system will generally not produce sustainable improvement. Systematic learning focused on understanding the system and the factors that affect the results and actions based on that understanding can produce sustainable improvement.

Management seems to call for action as events occur. In a very large firm, the hard drive was stolen from a computer. The hard drive contained no proprietary or confidential information, but the reaction was to hire a security firm to close down as many potential security leaks as possible. Electronic surveillance was installed at all pedestrian exits from company buildings. "Random" searches of trunks of cars were conducted when cars left company property. Employee access to fax and copy machines and the internet was restricted. In another case, a large factory put locks on gas pumps on the company property as a result of a single incident of an employee putting gas in his personal car from a company gas pump. Review of performance indicators leads the management of an organization to ask why certain numbers went in the wrong direction; for example, overtime costs went up the most recent month over what they were the previous month, or sales went down this month below what they were for the same month last year. Employees come to expect requests for explanations so they spend time preparing explanations that will appear to be plausible. These examples illustrate two common errors that can occur in reacting to events without correctly taking context into account.

Deming identified both of the errors illustrated above. One of these errors is to change the system in reaction to a special cause. For example, a single event occurs and a new policy is instituted. Or a single event occurs and a new regulation is put into effect. The actions taken to increase security in reaction to the theft of one hard drive is an illustration of this kind of mistake. The system changes to increase security resulted in great expense to the company for what could have been little reason. In the case of theft of gasoline, no action was taken to deal with the employee – the "special cause." "Can't let that happen again" thinking produced an action that led to loss of time for highly-paid employees; they now had to fill out forms and check out gas pump keys to use a company car to go on a business trip. Overreactions to what could be rare events can be extremely costly in terms of the human energy required to cope with an increasing number of policies and regulations. When there are legitimate signals of the action of special causes, the appropriate action is to identify the special cause and then take further action on the special cause only when the special cause makes results worse and is relatively likely to occur again or carries with it a catastrophic cost.

There has been a special cause signal in the case of atmospheric carbon dioxide levels. The most likely special cause has been identified as large scale burning of fossil fuels. The catastrophic costs of global warming justify action to drastically reduce large scale burning of fossil fuels. Rather than to address directly the issue of fossil fuel burning, there are other proposals that are generally called "geo-engineering." The proposals include (1) sequestration of carbon dioxide in deep ocean trenches or underground, (2) space based mirror arrays, (3) dust and soot delivered into the atmosphere with high altitude balloons and large guns, (4) aluminum powder and barium oxide sprayed into the troposphere by commercial and private aircraft to increase cloud cover and reflect more heat out into space, (5) sulfur burned by ships to increase cloud cover, and (6) adding iron oxide to oceans to stimulate mass plankton growth. These proposals involve attempts to deal with the consequences of large scale burning of fossil fuels, rather than to address that special cause directly. The consequences of adopting these proposals are not fully understood and, in some cases, are known to be harmful. For example, one consequence of burning sulfur is acid rain, which is known to kill forests. Deforestation leads to increased atmospheric carbon dioxide.[21] Any technique that targets earth surface temperature reduction without consideration of reducing carbon dioxide levels fails to address the devastating problem of ocean acidification which occurs as carbon dioxide is absorbed by the oceans. Addressing the special cause directly appears to carry far less uncertainty. Applying "band aids" that address symptoms often carries unintended consequences and results in increased cost. This may be the case with our planetary problem as well as in business.

The other common error in interpreting fluctuations in results is what Deming called "tampering." Tampering occurs when a special cause explanation is sought for every fluctuation in a series of results that are in statistical control and managers react to the explanations by making changes. We are assaulted every day in the news media by special cause explanations for common cause variation. The accounting systems in organizations sometimes help managers seek special cause explanations for random fluctuation by presenting data in tabular form that ought to be plotted as a simple time series graph including more than two time periods. To seek an explanation for why this month's figure for some type of cost went up this month over what it was last month

[21]A few climate scientists have, nevertheless, seriously considered introducing sulfur into the atmosphere. One of these scientists is Nobel laureate Paul Crutzen. He expresses concern that nations will not soon enough and seriously act to reduce carbon dioxide levels and the sulfur approach may have to be used to stave off complete disaster. See Crutzen, P.J., "Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?" *Climatic Change*, 2006, 17.

without having access to the context provided by the degree of variation seen in the past is to invite an erroneous explanation. Production costs per unit produced may have increased this month over last month, but it may simply be fluctuation of the same size generally seen in the series of past costs per unit. When a series of results is statistically controlled, tampering will increase the variation.

Often, increases in variation are accompanied by additional strains on the system. A large food products company had a sales group that had a practice of conducting grocery store promotions when sales volume went down from one period to the next. Since sales without promotions would have had volumes that were statistically controlled, the net effect was to create greater variation in volume. This, in turn, produced larger fluctuations in demands placed on the production system and the network of suppliers to the organization. Manufacturing executives had responded by building inventory, adding significantly to the costs of producing the products. The net effect was to reduce margins. Sales executives were judged to be successful if sales volume went up month to month, even though the net effect on the company’s profits was negative. The use of narrow objectives for different functional groups in the company produced the opposite of what was desired.

Some knowledge about variation, combined with a good understanding of the interdependencies among functions in an organization, can produce different approaches to managing an organization from those often used for lack of an alternative. A synthesis of appreciation for an organization as a system and knowledge about variation provides an alternative that can produce sustained improvement in performance. Knowledge about variation is also essential to understanding the causes of climate change and to finding solutions that address those causes.

Theory of Knowledge

Everyday business activity involves prediction. Staffing decisions, financial decisions, procurement decisions, production plans, project plans, marketing plans, and every other decision-making and planning process of an organization involve prediction. Likewise, development of business strategy must include the essential step of prediction. Deming repeatedly stated “management is prediction.”[22] He could have substituted the word living for management in his statement. There is no better example than the issue of dealing with the world’s climate. Respected scientists the world over have issued a warning that involves prediction: if decisive actions are not taken to significantly reduce the carbon dioxide put into the earth’s atmosphere by use of fossil fuels, the results will be catastrophic. On an individual level, each of us makes everyday decisions based on predictions of what is likely to happen. We decide whether to spend the day outdoors depending on the weather forecast (prediction). We decide when to leave for work depending on our estimate (prediction) of travel time. We decide whether to make a particular investment based on predictions of the risks and potential returns.

[22] Deming, W.E., *The New Economics 2nd Ed.*, MIT Press, 1994.

Rational Prediction

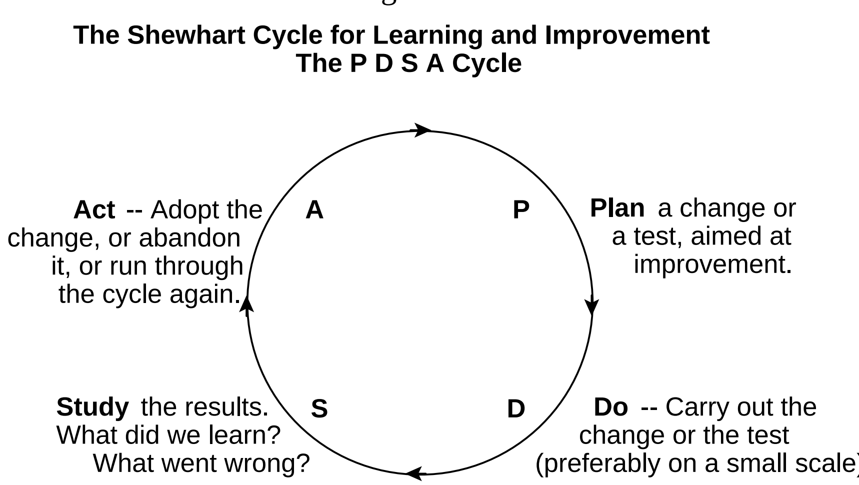
Deming spoke of rational prediction. We can predict anything we want: we can predict that the high temperature in New York tomorrow will be 148 degrees and the low temperature in Cairo will be 2 degrees; we can predict that sales of a product will triple next year; we can predict that the Chicago Cubs will win the World Series this year. However, if we wish for our predictions to have a chance of being correct, we need to have sound reasoning, that is, a sound rationale to support the prediction. Deming argued that rational prediction requires theory. Some who consider themselves to be practical would scoff at such an idea. For them, theories are for the ivory tower. However, we all use theories to plan and to act, whether we recognize it or not. The economist Keynes stated, "Practical men who believe themselves to be devoid of any intellectual influences are usually the slaves of some defunct economist."[23] Theories and models we construct form the basis for prediction, and consequently for planning and action.

It would serve us well to understand something about the theories that form the basis of our predictions. A stunning example has been presented in the form of the economic crisis of 2008 and 2009. Many holders of 401Ks had thought that their investments in the stock market were completely safe. This belief may have been based on the advice of financial advisors who explained that diversification of investments in the market protected against loss. Actually, the protection provided by diversification within the stock market doesn't provide protection against overall market risk. This misunderstanding of theory and the additional assumption that the future would be like the past contributed to an unpleasant surprise.

The Shewhart Cycle

Theory enables learning and improvement through the use of scientific method, described by Deming in what he called the Shewhart Cycle. Figure 10 shows Deming's description of the Shewhart Cycle – the PDSA Cycle. Use of scientific method involves the building

Figure 10[24]



[23] Keynes, J.M., *The General Theory of Employment, Interest and Money*, 1936.
[24] Deming, W.E., The New Economics, 2nd Ed., MIT Press, 1994.

of knowledge through comparison of observations with predictions made on the basis of a theory. When observations agree with predictions, degree of belief that the theory is correct is increased. When observations disagree with predictions, questions arise as to the source of the disagreement, trials that yielded the observations are repeated, or theory is revised or even abandoned. When there are competing predictions, as there are in the case of global warming, the soundness of the work that has gone into development of each prediction must be evaluated so that degree of belief in different predictions may be assessed. "Judgment of the relative substance of the theories underlying each prediction, the degree to which such theories have been tested in use and by peer review"[25] must be taken into consideration.

Knowledge is built through the systematic and continuing use of the PDSA cycle. Deming advocated the same practice in business to systematically improve products and services and business performance. Knowledge of the earth's climate and the factors which affect it is being built using scientific method with the participation of scientists throughout the world. Similarly, knowledge that will form the basis for new energy technologies will be built using scientific method.

Theories Help Us Understand Experience

We should use existing theories to help us understand experience – what happens in the business world and in the physical world. Deming said, "to copy an example of success, without understanding it with the aid of theory, may lead to disaster."[26] One of the most popular business books of the twentieth century involved the authors selecting forty-three businesses that they identified as great performers. Then they observed what each was doing and identified rules for doing well from their observations. So far as we know, they did not attempt to disprove their rules by identifying unsuccessful organizations and seeing whether they were also following some or all of the rules. Within a few years, some of the forty-three were in serious difficulty. Although the study might have been a place to start exploring some ideas about business performance, their rules were unable to stand up to even the test of further near-term observations. As Shewhart stated, "empirical evidence is never complete," and theories are subject to ongoing revision.

Theory of knowledge deals with what we know and how we know it. According to Deming, theory of knowledge "teaches us that a statement, if it conveys knowledge, predicts future outcome, with risk of being wrong, and that it fits without failure observations of the past." Knowledge is built by looking through the window of theory. Deming argued that information is not knowledge. As Deming said, "without theory, there is no way to use the information that comes to us on the instant."[27] To enable continued life and economic development, managers, scientists, educators, and members of government will need to develop and use new knowledge.

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[25] Dr. Ian S. Bradbury, personal communication 8/21/09.
[26] Deming, W.E., *The New Economics, 2nd Ed.*, MIT Press, 1994.
[27] Deming, W.E., *The New Economics, 2nd Ed.*, MIT Press, 1994.

New Knowledge

W. Edwards Deming once posed this question to a class of MBA students: "Where does new knowledge come from?" After his question was met with silence, he answered it himself: "New knowledge comes from the innately curious individual – responsible to no one."[28] Deming pointed out that information is not knowledge, and experience is not knowledge. But if information and experience can get us to think, and if in thinking we develop new theories to be explored, new knowledge can be born.

The history of climate change is the history of innately curious individuals: individuals like Jean-Baptiste Fourier who in 1827 wrote a paper describing a phenomenon he called *the greenhouse effect*. Fourier theorized that the only way the earth could maintain the comfortable temperature of 57° F was if the atmosphere acted like the glass of a greenhouse, capturing some of the sun's energy as it reradiates back out into space. Some thirty years later the independent scientist Dr. John Tyndall showed how water vapor and CO_2 absorbed infrared radiation, giving credence to Fourier's theory. Then in 1895, after a year of tedious hand calculations, Svante Arrehenius estimated the increase in global surface temperatures due to increased concentrations of CO_2 in the atmosphere. All three of these men were innately curious individuals who created new theory.

Today, those who continue to question the validity or urgency of human-induced climate change often dismiss it as "just a theory." Yet, human civilization has been built on theory. Without Newton's theories of gravity and motion, there would have been no industrial revolution. Without Darwin's theory on the origin of species, modern natural science would not exist. And without Einstein's Theory of Relativity human knowledge of the universe would be stunted. The greatest achievements of Newton, Darwin and Einstein were their theories – and those theories reshaped mankind and our planet. Climate change theory is already shaping the future and changing the ways humans interact with our surroundings – and it is opening the door to new knowledge.

Business as Usual or Transformation?

In the mid-1960's a Dutch chemist named Paul Crutzen began studying the effects of chlorofluorocarbons (CFC's) on the earth's atmosphere. CFCs are man-made chemical compounds invented in the 1930's and put into wide industrial use by the 1960's. Crutzen's research was showing that CFCs were rapidly destroying the protective ozone layer of the earth's atmosphere. Backed by this science, governments in the 1980's forged an international agreement for the regulation and reduction of CFCs. Crutzen went on to share the 1995 Nobel Prize in chemistry for his important contribution to the science.

Crutzen's experience with CFCs made him aware of the power of human industry to change the physical world on a planetary scale. Not only had human industry come very close to destroying the ozone layer, but it was in the process of reconfiguring the chemical composition of greenhouse gases in the earth's atmosphere. By the year 2000, Crutzen was asserting in scientific publications his belief that the earth had entered a new

[28] Deming, W. Edwards, Lectures at Columbia University, Spring, 1991.

age – in fact a new geological epoch.[29] The *Holocene* period, which began at the retreat of the last ice age, was over and the earth now found itself in the *Anthropocene* – an entirely new chapter in earth's history defined primarily by the impact of human activity on the planet.

The Anthropocene era (*anthropos* is Greek for human being) represents unique challenges to humanity and to business. The biggest of these challenges is sustaining a vital global economy while addressing the urgent issue of climate change. Climate change is different from any problem business has faced in the past. Yet, in one respect it is similar to a problem America has been facing for decades – competitive decline. America's decline and climate change are similar in that they both represent systems problems. In part, competitive decline was the consequence of a lack of appreciation for business as a system; climate change is the consequence of a lack of appreciation for the interdependence between the global economic system and the earth's biosphere.

Two decades ago, W. Edwards Deming called for changing the ways of American management in order to address America's competitive decline. He knew that tweaking business-as-usual practices would be ineffective and indeed counterproductive. Transformation was needed, and it had to be informed by knowledge. Today we are living in a new geological epoch, where the term 'business-as-usual' refers to the continued practice of burning fossil fuels. Some in industry are advocating sticking to business-as-usual or perhaps tweaking it around the edges. But such action will be ineffective and indeed counterproductive. A great transformation is required to avoid the worst consequences of a warming world – a transformation that aligns the global economy with the workings of the earth's ecosystem. This transformation will impact every enterprise in the global economy and will require skillful management informed by new knowledge – the very same ideas Deming introduced to transform management.

How companies will organize in the age of human-induced climate change will depend on whether management chooses to operate in a business-as-usual mode or to incorporate profound knowledge into their thinking. The following nine organizing principles give a sense of the differences.

	Business As Usual	**Using Profound Knowledge**
1	Focus on **competition**	Alert to opportunities for "**coopetition**"
2	Management through **division** and **compartmentalization**	Management informed by an understanding of **interrelationships** and **interdependencies**
3	Management sees **disparate** economic, social and environmental security needs	Management realizes the **interdependence** of economic, social and environmental security

[29] Crutzen, P.J. and Stoermer, E.F., "The 'Anthropocene, '" *The International Geosphere-Biosphere Programme (IGBP) Newsletter*, 41, May, 2000.

	Business As Usual	Using Profound Knowledge
4	Management sees the future of business like the past; e.g., ever increasing in **energy intensity**	Management examines potentialities for a transition from energy intensity to **information intensity**
5	Addressing climate change is seen as a **burden**, putting American business at a **disadvantage**, killing U.S. jobs	Addressing climate change is seen as a **transformational opportunity** to build a sustainable U.S. economy and boost global competitiveness
6	A quick solution to climate change would be to **geo-engineer the climate** to align with human needs	The long-term solution to climate change is to **align the human economy** with the workings of the biosphere
7	Appoint a **Chief Sustainability Officer**	Executives **learn** about climate change and sustainability and **accept responsibility** to lead the organization’s efforts
8	Business is highly quantifiable and the task is **to manage what you measure**	**The greatest gains and losses cannot be measured**, but they must be managed
9	Profit is the **aim** of a well-managed business	Profit is a **consequence** of managing well

Aerojet Rocketdyne's InThinking Network Ongoing Discussion
September 2013
Andrew McKeon – Thinking About Management from a Climate Change Perspective

BIOGRAPHY

Andrew McKeon founded BusinessClimate to provide consulting services that help clients create value in ways that foster sustainability while increasing their global competitiveness and profitability.

He has organized the annual conference BusinessClimate to gather global leaders in sustainability to explore the technology, policy and management transformations which are necessary to build a resource efficient low-carbon economy. Underlying what is perhaps the greatest business opportunity of the 21st century, Andrew believes there is an organizing principle akin to Moore's Law, which lent predictability to the growth of the semiconductor industry and built today's information economy in which we live and work.

Andrew has held the position of MTS (Member of Technical Staff) at AT&T Bell Laboratories (now Alcatel-Lucent) and, thereafter, worked as an operations and control specialist in derivatives at Goldman Sachs and Vice President and Business Area Controller at Deutsche Bank. In 2006, he began working with US Vice President Al Gore in raising awareness on climate change.

Andrew has been a sought after speaker and instructor on climate change and technology. His writing has appeared in such publications as Greenbiz, Reuters, and strategy+business magazine. He has been invited to speak at NASA, the United Nations, the Deming Biennial, and was a keynote at the IEEE sponsored PICMET 2009. He is an advisor to the UN-GAID and is a member of the Board of Directors of TransitCenter.

He holds an MS in Mechanical Engineering and an MBA, both from Columbia University.

CONTACT

Andrew McKeon can be reached by e-mail at amckeon@carbonrational.com for additional information about this Ongoing Discussion.

WEBSITE

www.carbonrational.com

LINKEDIN

www.linkedin.com/in/andrewmckeon