Life-Cycle Thinking: What can *IT* do to be green?

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ABSTRACT

Sustainability is a critical theme in transforming both our environment and our society to adapt to the rigorous demands of the future. This paper serves an educational purpose, and introduces the central concept of sustainability; *life-cycle thinking*. Three fundamental problems are discussed with the purpose of highlighting the importance and awareness of energy use, environmental protection, and the potential for climate change. Our current industrialized economy is highly dependent on non-renewable fossil fuels that have many negative effects on our way of life, and it will take the combined efforts of every sector of society to develop suitable alternatives. In response, this paper examines the role of information technology (IT) in assisting sustainable activities which can transform our economy, environment and society. We discuss several opportunities for change, such as innovation, new technology adoption, manufacturing, cyber-infrastructure, IT management for campus operations, and IT research into sustainability activities, etc. in the context of how information technology – and *i*School activities can support transformation to a green economy. In conclusion, the importance of green activities - and research into opportunities for sustainability are emphasized.

Categories and Subject Descriptors

K.4 [**Computers and Society**].

General Terms

Reliability, Management.

Keywords

Sustainability, Campus Operations.

1. INTRODUCTION

Our society was agriculturally-based up until approximately 1900, when the industrial revolution enacted major social changes on just about everything. With the discovery of oil, industrial production and transportation became cheap, and our entire culture was shifted accordingly. Families could move farther apart, yet still see one another. The workplace could be farther from the home. The food we eat could be grown in California and shipped to New York without adding much to the overall life-cycle cost. As we now come to the end of this era of cheap energy, we will have to change consumer behavior by re-localizing our lives, paying special attention to the life cycle of the goods and services that sustain us. We need to re-examine the ways that we interface with the global economy to figure out what makes sense with regards to sustainability. We need to migrate our communities to focus on using products and eating foods that are produced locally and/or require less energy - to reduce the use of carbon-based fossil fuels.

We had mechanistic worldview even before our industrialization [2, 15]. A mechanistic perspective does not take into consideration the interconnectivity of our many disparate systems (or elements). The mechanistic / industrialist world-view encourages us to look at things as separate components rather than understanding the integration of systems. But in fact, as in the natural world, everything needs to be integrated for sustainability cycles to be maintained. The mechanistic perspective is a useful model to observe, but we must move beyond this to look at systems in a larger perspective befitting a lifecycle analysis.

Our current economy is not sustainable; all our major systems are based on fossil fuels that are now becoming more and more expensive. This basic truism will have a huge impact on transportation systems, food production systems, manufacturing systems, economic systems, and our most basic life-support systems as well. In our society, there has been virtually no thought given to the large-scale sustainability of the basic fundamentals required for day-to-day survival. For example, despite the fact that the majority of advanced society eats meat at most meals, this diet is not really sustainable. Worldwide, we do not have enough productive farm land to sustain the earth's population through conversion of plant matter to beef and then to humans. As a result, humans will eventually be forced to eat lower on the food chain. This is just one example of how increasing populations will require re-thinking of basic human needs.

An even more compelling example might be the way we have come to think about waste. Product designers have been trained to design obsolescence into the development of all products; useful for a period of time, and then discarded so the consumer buys again. This creates a cycle of waste that is now threatening the health and well-being of the entire industrialized world. Landfills

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are building up at an alarming rate, and cities are being forced to spend significant money to separate this waste from the people creating it. In response, our entire product life-cycle needs to be reformed. And we need sustainability to be worked in to every part of our human life-cycle as well.

The characteristics that made our civilization great now actually threaten to overwhelm us. But the many problems we face can also be viewed as opportunities. Overall, we have the opportunity to make the world a better place for our future generations. If we do not, we will face a world of scarcity and struggle. So the need to re-think our activities in a holistic way also offers us the opportunity to correct some mistakes we have made. The consumerist petroleum-based economy that has created so much wealth is now starting to unravel. The system that will replace the current economy is now being referred to as the “green” economy.

In order to enable the green economy, we must each ask a question in everything we do: “Is it sustainable?” People need to have the sustainability infused into their mental framework for all things created, generated, built, manufactured, operated and managed. As such, life-cycle thinking must also be included when we are shaping and re-shaping information systems for the benefit of our society. This will enable information technology (IT) to support the movement towards a sustainable green economy.

2. FUNDAMENTAL PROBLEMS

There are three fundamental problems in the industrialized societal development which impact the future of our society.

2.1 The End of Inexpensive Energy

The use of fossil fuel in our current economy is still growing exponentially, yet supplies within easy reach are diminishing [1]. We are on the downside of the bell curve that represents oil supplies while demand continues to rise. As Figure 1 depicts, the exploration and extraction of oil development that started in the mid-1800’s has increased steadily ever since, but it is now widely recognized that accessible supplies are being used up [19].

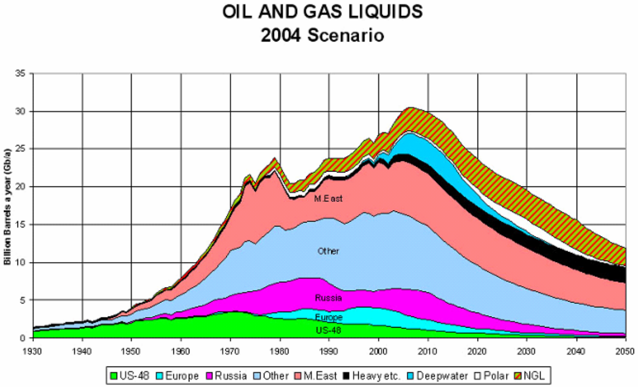

Figure 1: Oil and Gas Liquids 2004 Scenario

According to Duncan’s Olduvai Theory, it is becoming increasingly difficult to locate and obtain fossil fuels [5]. Fuels are not exactly running out; but, developers will have to go deeper and farther to obtain fossil fuels. Meanwhile, our whole first-world economy is totally dependant on fossil fuels – civilization as we know it requires an endless supply of low-cost energy. In addition, much of the under-developed world is now looking to emulate the western civilization. This means that the cost of all energy, commodities, and even the most basic necessities, will continue to rise accordingly.

2.2 Environmental Degradation

The environment we are living in is constantly being degraded [18]. This depletion of resources includes even the most basic necessities; air, water and soil. Our ecosystems have become damaged and our life support systems have become significantly compromised. The degraded and polluted environment results in poor health across the population, for example; cancer, asthma, toxic chemical build-up, etc. Poor health amongst the population also results in increased health costs, and adds to the complexity of possible solutions. The costs of re-claiming the environment, and the costs associated with shielding the populace from the harmful effects of large-scale environmental degradation will inevitably start to have an impact on the costs of all goods and services.

2.3 Climate Change

In a long-term evaluation of the climate, human activities in general may be starting to affect the atmosphere. Changes recently noted by scientists worldwide include a rise in average global temperatures, revised patterns of high-altitude wind channels, rising sea levels as a result of deteriorating structural ice around the world [9, 14, 21]. Carbon dioxide[1] levels (parts per million) are rising worldwide at an alarming rate [16], and other “greenhouse gases” are also rising in patterns that are uncharacteristic of natural cycles. As Figure 2 depicts, the rise in greenhouse gas may be causing an increase in global temperature that cannot easily be reversed [19].

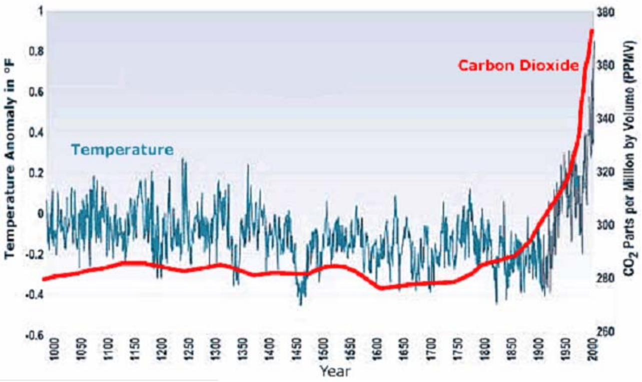

Figure 2: Rising CO associated with higher global temperatures

Recently, it is becoming generally accepted that weather patterns are becoming increasingly unpredictable. There is basic agreement among top scientists worldwide that these climactic changes are being caused by the non-sustainable activities of humans, and this may be drastically affecting the environment we are living in [8].

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[1] Same as CO_2.

3. LIFE-CYCLE THINKING

The mechanistic world-view began to dominate our society in the sixteenth and seventeenth centuries, encouraging scientists to look at things as separate components rather than parts of integrated systems [2, 15]. Consequently, natural systems began to be looked at in the same way that industrial designers looked at machines. Integration points were defined in the natural systems, with very few organized attempts to understand the larger ecosystematic infrastructure as a whole. When society moved away from its agricultural base, it also moved away from the associated natural world-view. Industrial society was defined by the machines that started to gain widespread acceptance as a sign of progress. Today, it is time to realize that we lost some very important lessons in this transformation.

In nature's economy, nothing is ever wasted. Everything is used, recycled, and re-used. When animals die in nature, the carcass provides food for other animals. When plants die, their decayed remains become nutrients for other plants. Leaves fall from the trees and become compost to sustain the same tree. Nature provides many examples of this type of natural recycling of nutrients.

Adopting the same basic principles, our design strategy in all human engineering endeavors should include life-cycle thinking. The concept of "cradle to grave" (products used and discarded) has characterized product design strategy since the dawn of the industrial age. However, as we go forward this strategy has to be replaced with the concept of "cradle-to-cradle." Products need to be designed in a way that when their useful life ends, there is a plan. Used plastics need to be collected, shredded, and processed to become the raw materials for new plastic products. Metals from old cars or machines need to be separated and melted down to produce the raw materials for new cars and machines.

The concept of recycling - and doing more with less - is critical for all sectors of society. As such, it needs to be encouraged in IT innovation, adoption, manufacturing, cyber infrastructure-building, operation, and management. The IT community should infuse life-cycle thinking into all facets of information systems innovation.

4. *IT* ENABLING THE GREEN ECONOMY

In the context of life-cycle thinking, we present several examples of how information technology can enable the next "green" economy in real-time practical ways.

4.1 IT Innovation

To understand how we use energy is the first step. Information systems are being built to easily calculate energy use (and waste) of individuals, and entities such as a building or a manufacturing process.

4.1.1 Carbon Calculators

Carbon is one of the more prevalent greenhouse gases [13]. Human activity cannot help but create carbon dioxide. Even so, the carbon-producing activities of most Americans have dramatically exceeded those of most other countries. However there are many ways to reduce carbon. The amount of carbon one produces is referred to as one's "carbon footprint" [11]. The first step to reducing an individual's carbon footprint is to figure out how much carbon his or her activities generate. Carbon calculators are one of many IT innovative examples. They require an individual to input key data about his or her life activities, and then calculate the amount of carbon produced as a result. Once an individual understands what activities create the most carbon, modifying one's life style can be planned to reduced one's carbon footprint. There are several carbon calculators that have been developed:

- Nature Conservancy[2]
- Clean Air Cool Planet[3]
- Empowerment Institute[4]

The technology and design of each carbon calculator listed here reflects a slightly different focus, and each will yield a slightly different number to characterize the carbon-generating activities of the end-user. But the IT community is making a significant contribution regarding technological design and innovation in continuing to refine the algorithms that define society's carbon footprint. The real and required improvement lies in reducing carbon emissions by calculating and educating society as to how much carbon each individual has produced as we try to improve.

4.1.2 Building Modeling Software

IT can also help estimate the amount of energy we use in the life-cycle of our living spaces, and the amount of energy we can save. Building modeling software is another example of IT innovation, which makes it easy for building professionals to calculate energy use and identify key activities that can reduce energy waste. When energy bills are included and validated as part of the modeling, the model can be "calibrated" with such precision that it is possible to determine exactly what energy-saving improvements will yield the best results with a high degree of accuracy.

The National Renewable Energy Lab (NREL) has developed SUNREL™, a physics calculation engine that is useful in the modeling of the building's life-cycle for energy purposes [4]. This engine is an energy simulation program that ensures that occasional dramatic changes in temperature do not affect the overall calculations of energy use. Because the amount of energy used is greater when outdoor temperatures are significantly different than indoor temperatures, dramatic weather fluctuations must be taken out of the equation in order to maintain the accuracy of building modeling.

An example of IT innovation built upon this SUNREL physics engine is a software product, called TREAT[5] (an acronym for Targeted Residential Energy Analysis Tools). TREAT is a set of energy analysis tools for modeling the energy consumption of buildings, as a means to identify the most cost-effective energy efficiency upgrades for both single-family and multifamily buildings. TREAT allows building professionals to make educated decisions about how to eliminate energy waste. TREAT is one example of how software can make a significant impact on

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[2] www.nature.org/initiatives/climatechange/calculator/

[3] http://dev.cleanair-coolplanet.org/toolkit/inv-calculator.php

[4] www.empowermentinstitute.net/lcd/lcd_files/LCDcalcNet.html

[5] http://treatsoftware.psdconsulting.com/

human activity, with the goal of reducing energy use, energy waste, and the carbon emissions that result. The IT community has the potential to make many significant contributions to help make human activity sustainable, and the list is limited only by our collective imagination.

4.2 IT Adoption

Information technology can be adopted to assist with the task of reducing energy waste. A few examples below demonstrate how life-cycle thinking is infused in IT adoption, which improves a sustainable community.

4.2.1 Programmable Buildings

The heating and cooling of buildings produce bulk of carbon worldwide. Many opportunities exist to improve building performance by using technologically-based improvement strategies. For example, real-time web-based monitoring and automated control of building operating systems can help to solve building performance problems as they occur. Simply adding a programmable thermostat can result in significant energy (and carbon) savings to a building's operating system. This single example of information technology adoption can pay for itself in a short period of time. Automated sun-shading, automated ventilation systems, and automated lighting control can all make a huge difference if appropriately adopted and maintained.

4.2.2 Benchmarking Building Tools

To make educated decisions regarding the building performance of large non-residential buildings, IT offers the opportunity to make comparisons regarding energy within a community. One example of this is the benchmarking of building performance[6]. Benchmarking allows for building comparisons that can help building owners and operations managers to make useful decisions about where to implement energy-based improvements.

Benchmarking sets a baseline for energy utilization, whereby a building can be compared to other buildings of similar size and use-type - and to itself over time. This is initially helpful in determining which buildings (in a group) need the most improvement. Once improvements are made, tracking the performance of a building's systems can provide important data that can be used to maintain or increase energy efficiency and reduce carbon emissions. Long-term reporting is required to determine the effectiveness of energy/carbon reducing efforts over time. Underneath the user interface for benchmarking tools, there is a database and a set of algorithms. Data from utility companies - from energy improvements – from carbon footprint measurements – and more - are archived and used to make important decisions on energy use and energy waste.

4.2.3 Power Surge Switching Technology

Another example of IT adoption is the study of switching undesirable power surge [3] because power surges can reduce the efficiency of the power supply, and consequently the amount of power drawn by computer accessories when they are not being used.

4.2.4 Smart Grid Technologies

On a larger scale, "smart grid" technologies are just starting to be considered by utility companies that have a vested interest in meeting the power demands of their customers. Smart grid technologies are defined as a digital upgrade of distribution and long distance power transmission using a combination of advanced communications, strategically-placed sensors, and distributed computer controllers to improve the efficiency, reliability and safety of electricity delivery and use [12]. IT is a critical element of this new and over-arching vision for an intelligent infrastructure that seeks to deliver power to end-users instantaneously - based on real-time use requirements.

4.3 IT Manufacturing

From a direct aspect of life-cycle thinking, computer components, devices, or production lines, etc. need to be redesigned and re-engineered according to the concept of "cradle-to-cradle." Computer systems need to be developed and manufactured to reduce waste, not produced as a one-time use commodity. Laptops and their components should not be disposable. They should be designed to last longer, and then to be recycled. Components should be replaceable and upgradeable in a cost effective manner. The social and environmental implications of the entire life-cycle of IT components (such as computers, monitors, keyboards, etc.) - from the source of raw materials - through to the production and ultimately disposal - must be taken into account.

4.4 Cyber Infrastructure

When implementing cyber infrastructure, life-cycle thinking should also be planned and incorporated into network infrastructure design. For example, alternative solutions for less energy and resources should be put in the client-server architecture.

4.4.1 Thin Client Computing

When planning a client-server architecture network, a processing server can be placed centrally, with multiple thin clients connected to its services. A thinner client[7] can allocate more processing activities to the server, and require fewer servers to accomplish relatively the same processing.

4.4.2 Software-based vs. Hardware-based

To further reduce resource requirements, software-based routing or firewall solution should be considered more desirable than having a hardware-based routing or firewall solution.

4.4.3 Virtual Machine

The use of virtual machine provides high-level program representation, which allows large networks to be programmable in a simplified and energy-efficient manner [10].

4.4.4 Grid Computing

Grid computing is a scalable, distributed networking environment where a clustered computers work together to solve a single problem. The fact that grid computing utilizes the processing

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[6] Compass is an example of a benchmarking tool for large buildings.

[7] such as http://www.ncomputing.com/

power from distributed thin clients can replace the needs of using supercomputer [6]. Grid infrastructure will enable power usage on each thin client. When a thin client is turned on, it can share some unused processing power to solve another task that requires much processing power in the grid environment.

4.5 IT Management for Campus Operations

*i*Schools should be more than just an "engine of innovation," but should take a leadership role in reaching out to the community to drive ecosystematic thinking in local systems. To be effective in this way, sustainable life-cycle thinking needs to be integrated into all *i*School activities.

4.5.1 Campus Life-Cycle

"Buying green" is a concept being promoted by a government-based program called EPEAT[8]. Energy Star standards have been widely adopted for government purchases at the Federal, State, and Local government levels. Additional requirements around reducing packaging waste and management for product end-of-life should be engineered and designed for environment.

All purchasing decisions should be made with thoughts of sustainability. Reusing things that are typically thrown away has an important role. For example, when SUNY New Paltz[9] required new desks because of worn desk-surfaces, instead of purchasing new desks, a decision was made to turn over the desktops themselves and reuse the desks instead of buying new. In this case, students have new desk surface to use, and schools can be exempted from purchasing new desks. There are many examples of ways that resources which are typically wasted can be utilized to reduce the purchasing requirements of school operations, and every instance that results in less manufacturing also results in a reduced energy use and carbon emissions. For example, typically lockers are cleaned out at the end of each academic year, and the leftover contents are discarded. In a forward-thinking *i*School, a green staffperson could be positioned in the school maintenance department, whose role is to clean out those lockers, and recycle useful supplies among incoming students.

Re-lamping (replacing incandescent light bulbs with compact florescent lamps), and perhaps ultimately LED bulbs (light-emitting diode) provides easy and effective ways to reduce energy and carbon when applied campus-wide. Education on "green" behaviors, such as closing windows and turning off lights when not being used, are critical practices in reforming basic campus activities.

4.5.2 Reuse and Recycle Hardware

Re-use and recycling of hardware for computer labs should be considered as part of student education. For example, Google recycled old AT computers to build servers for the infrastructure and foundation for what has become a huge industry of data aggregation. The fact that Google chose to utilize out-dated equipment - rather than purchase new servers - was a decision based on cost as well as resource management [7, 17]. Google serves as a role model and an example of the many creative opportunities that exist for IT.

4.5.3 Forming Action Groups

Sustainability action groups for energy efficiency and climate protection initiative can be formed and organized on campus. *i*Schools should form such committees for ongoing localized coordination with the national Association for Sustainability in Higher Education (AASHE) in publicizing and encouraging green activities in campus activities and operations.

4.6 IT Research into Debatable Activities

There should be more research encouraged regarding sustainable activities in information technology. The issues of sustainability in information technology are complex and far-reaching. For example, the debate on whether to leave hard-drives spinning when not use (which uses more electricity) versus shutting computer down (which means more "wear and tear" on the hardware – leading to earlier disposal) needs resolution. Addressing issues like this is referred to as "triple bottom line." The term, "triple bottom line" refers to the uses and impacts of information technology on 1) economy, 2) environment, and 3) society. Life-cycle considerations must include an expanded spectrum of values and criteria for measuring organizational / societal acceptability.

5. CONCLUSION

Nature showcases competition in many ways. However, from a high-altitude perspective, such competition is a very refined level of cooperation. The eagle feeds on the mouse, but each player in this life-and-death struggle is also part of a larger dance of life, where mice are free to grow, and where the eagle has its own predators to deal with. The concept of "coop-etition" is one that our societal planners must adopt, to place the interests of the masses (and future generations) before the interests of the individual. The synergistic planning of integrated sustainability needs to be ingrained in our societal systems at all levels.

Our current society, based on non-renewable energy and non-recyclable waste, is in jeopardy of driving off a metaphorical cliff. Modern civilization as we know it could end if we can not find ways to transform our current activities, and make them sustainable. Our society must meet the needs of today's activities without sacrificing the well-being of future generations. This is the responsibility of all citizens in all sectors, but IT plays a critical role which must be addressed. Being able to recognize and promote sustainable activities while providing research in sustainable IT options ultimately creates significant opportunities for green jobs in the IT sector. These jobs cannot be outsourced to distant lands. Green jobs represent opportunities created for workers in the homeland while enabling economic growth, reducing energy dependence, and improving the health of the populace. In the end, these green choices create an opportunity for students to align themselves with meaningful life goals that strengthen communities and the country as well.

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