APPLYING SUSTAINABILITY FROM A SYSTEMS PERSPECTIVE:
ADVANCING INDUSTRY THROUGH APPLIED RESILIENCY AND BIOMIMICRY

A Thesis
presented to
The Faculty of California Polytechnic State University,
San Luis Obispo

In Partial Fulfillment
of the Requirements for the Degree
Master of Science in Industrial Engineering

by
Timothy M. Brophy

June 2013

© 2013

Timothy M. Brophy

ALL RIGHTS RESERVED

COMMITTEE MEMBERSHIP

TITLE: Applying Sustainability from a Systems Perspective:
Advancing Industry Through Applied Resiliency

AUTHOR: Timothy Brophy

DATE SUBMITTED: June 2013

COMMITTEE CHAIR: Dr. Lizabeth Schlemer, Associate Professor IME Dept.

COMMITTEE MEMBER: Dr. Sema Alptekin, Associate Professor IME Dept.

COMMITTEE MEMBER: Dr. Roya Javadpour, Associate Professor IME Dept.

ABSTRACT

Applying Sustainability from a Systems Perspective: Advancing Industry Through Applied Resiliency

Timothy M. Brophy

Becoming sustainable is no longer an option. Current industry methods will not be able to support the necessary changes our growing society demands. In order to keep up with ever increasing demands industry will be aimed toward making major system changes toward a fully sustainable model. As of right now only basic sustainability actions have been put in place. Industry needs to make a strategic change toward resilient systems with an end goal of evolving into fully biomimic systems. This thesis covers a brief history of production leading to the Industrial Revolution which created a need for increased sustainability efforts. The Environmental Movement was started in hopes of creating these changes and is extensively studied in this thesis logically leading up to industry's current sustainable actions. A discussion of widely applied sustainability methods helps to describe a need for a framework that will help move industry toward increased resiliency. The culmination of this thesis is the creation of a three-piece framework for change, called RISE (Reshaping Industry Sustainably Efforts). This framework is the product of extensive research into current sustainability efforts, collected survey results, and the need to increase understanding of resilience and biomimicry from an applied system perspective.

Keywords: sustainability, resilience, biomimicry, applied sustainability, industry change, systems engineering, industrial engineering

ACKNOWLEDGMENTS

The writing of this thesis is the result of many people's patience, care, and love shown toward me.

Thank you Hailey, love of life, for always believing in me and constantly supporting me in my every endeavor. Without your support I would not have been able to get to where I am today. I know this is only the beginning of our journey together and only a glimpse of the things we will achieve.

Thank you Mom and Dad for raising me in the truth and nurturing my curiosities in engineering and higher education. Your meticulous patience and encouragement has created who I am today.

Thank you Hannah and Felicity for always looking up to me and believing in your big brother. You're my best friends and I can't wait to share our lives together.

Thank you to all my dear friends who all supported my academic efforts even when it meant I had to call it an early night. You made college a memorable experience and every all-nighter an adventure.

Thank you Liz for your guiding hand and countless effort in helping refine my writing and always challenging me. You are an amazing adviser and I'm so blessed to have had your help.

Thank you to the entire wonderful Cal Poly IME faculty for your hard work and true concern in helping your students. Your work is so very apparent in the success of Cal Poly graduates.

Table of Contents

LIST OF TABLES.....	vii
LIST OF FIGURES	viii
Chapter 1: Introduction	1
1.1 Problem Statement	1
1.2 Purpose and Scope	2
Chapter 2: Literature Review	3
2.1 History of Early Production, the Industrial Revolution, and the Environmental Movement.....	3
2.2 Defining Sustainability	24
2.3 Industry’s Current Place in Sustainability	27
2.4 Biomimicry	31
2.5 Toolsets	33
Mid-level Sustainability Analysis Tools.....	34
Sustainability System Change Tools.....	40
Chapter 3: Methodology	48
3.1 Summarizing the History of Sustainability	48
3.2 Best Practices	49
3.3 Designing the Current Activities Survey (CAS).....	50
3.4 Distributing the Current Activities Survey (CAS).....	50
3.5 “Reshaping Industry Sustainability Efforts” (RISE) Framework	68
Chapter 4: Case Study.....	76
Chapter 5: Conclusions and Future Directions	80
Bibliography	82
Appendix A.....	86

LIST OF TABLES

Table 1: Sustainability Tool Comparison	47
Table 2: CAS Respondents Summary.....	52
Table 3: CAS Survey Respondent Diversification	53
Table 4 : CAS Official Individual Statement Ranking	55
Table 5: CAS Individual Sustainability Statement Ranking.....	55
Table 6: ANOVA CAS Question #4.....	56
Table 7: Tukey Method CAS Question #4	57
Table 8: CAS Question #5 Likert Scale Values.....	59
Table 9: ANOVA CAS Question #5.....	60
Table 10: Tukey Method CAS Question #5	61
Table 11: CAS Question #7 Summary.....	65
Table 12: CAS Triple Bottom Line Averages	65
Table 13: RISE Framework	71
Table 14: Case Study CAS Q4.....	76
Table 15: Comparison to Official Ranking.....	76
Table 16: Case Study CAS Q5.....	77
Table 17: Level of Agreement	77

LIST OF FIGURES

Figure 1: World Population Growth	5
Figure 2: The Population Problem.....	5
Figure 3: Defining Sustainability Report Content ⁵⁰	35
Figure 4: Life Cycle	37
Figure 5: LCA Framework.....	39
Figure 6: Inputs and Outputs of LCA	39
Figure 7: Circles of Sustainability Diagram ⁴⁸	43
Figure 8: Circles of Sustainability Example ⁴⁸	44
Figure 9: Environmental Performance Index (2008) ⁴⁹	45
Figure 10: CAS Survey Respondent Diversification	54
Figure 11: CAS Individual Sustainability Statement Rankings.....	56
Figure 12: CAS Company Sustainability Per Question.....	59
Figure 13: CAS Question #5 Likert Scale Averages	60
Figure 14: CAS Company Sustainability Summary	62
Figure 15: RISE Waterfall	72
Figure 16: RISE Framework Part 1	73
Figure 17: RISE Framework Part 2	74
Figure 18: RISE Case Study Framework Example.....	79

Chapter 1: Introduction

Since the Industrial Revolution, humanity has exponentially increased its use of natural resources without much regard given to replenishment¹⁷. Our usage of these resources is based on a continual growth model which cannot be supported¹⁸. It is estimated that within the next ten to twenty years, without a drastic change in current usage and waste patterns, we will damage the environment beyond repair¹⁵. Action needs to be taken. It is not an overstatement to conclude that the largest and most demanding question of this century is how we will fully adapt to our environment and join the millions of other species that cohabit this planet without harm.

1.1 Problem Statement

Sustainability has been a point of concern for some time with customers, employees, and increasing legislature urging industries to reconsider how their products are taking a toll on the environment. In fact, stakeholders are expecting companies to lead sustainable initiatives rather than just manage risk when it comes to sustainability¹⁹. A quick internet search on sustainability initiatives will yield a plethora of results ranging from a simple company recycling program to full-blown company triple bottom line revamps but very few companies have taken the necessary action to model their businesses around sustainability³⁴.

Designing a system to be fully sustainable or even to begin becoming sustainable is very difficult and often daunting. Taking one step at a time with full knowledge of how to achieve the next step is how industry will succeed. Industry understanding of

sustainability can be fostered by increasing awareness concerning current sustainability techniques. This will make progress toward holistically resilient systems truly attainable.

1.2 Purpose and Scope

The purpose of this thesis is to both foster understanding in applied sustainability and encourage growth in sustainability by comprehensively investigating the current state of achievement in sustainable applications and defining the next steps in sustainable practices. In particular this report will guide industry members into a better understanding of sustainability from a systems perspective by logically walking them through the evolution of industry sustainability from basic sustainable initiatives, to designing a resilient system, to fully biomimic systems.

Upon reading this thesis, the reader will gain a thorough understanding of the reasons leading to the Industrial Revolution, the history of the Environmental Movement, the definition of sustainability, methods for companies to achieve truer sustainability, and steps to evaluate the progress of sustainable process redevelopment. This thesis will focus on industry increasing system sustainability rather than investigate details in legislature or personal ways to be more sustainable. In looking at industry, this report will examine industry systems as a whole in a sustainable sense with specific applications of applied biomimicry with an end goal of creating ecologically sound systems.

This thesis can be used as a guide in evaluating a company's level of sustainability from a holistic point of view by reading the application chapter but it is truly meant to provide a full background of where sustainability started and where it will eventually need to be. Thus, the reader is encouraged to not only use this thesis as a reference for action but also

as a way to quickly understand why sustainable practices are the focal point of the 21st century and how true sustainability is the key to future industry success.

Chapter 2: Literature Review

2.1 History of Early Production, the Industrial Revolution, and the Environmental Movement

To fully understand why our current methods of production and consumption are in need of being altered, and what solutions may prove viable, there must first be an understanding of society's current norms and where these stem from. The following section will start with the early history of production and then investigate the major events from the Industrial Revolution which shaped industry standards and set a consumption trend that is continuously and increasingly harming our planet. Next we will delve into how the Environmental Movement was started and the progress that has been made since then. Finally, we will discuss recent sustainability trends in industry, what we can learn from this history, and how this all plays into the solution.

The best place to start investigating human production is at the beginning of known human existence when production was survival. The cavemen would hunt only to gather what they needed (a sustainable method which until recently was used by many cultures such as the Native Americans). A wooly mammoth would be hunted, its meat used to feed many families, its bones served as weaponry, its ribs were used for roofs, and its fur used as clothing. Soon hunters realized that many wooly mammoths could be slaughtered at a time by running entire herds off the side of a cliff. Unfortunately it was not understood until it was too late that this hyper efficient hunting method was causing

the entire species to become extinct and is one of the first examples of a “progress trap” as deemed in Ronald Wright’s book, *A Short History of Progress*, sometimes progress isn’t always to the benefit of society³⁵. The fuller definition of a progress trap is when focusing on the progress made through developments leads to a failing to acknowledge potential problems that may arise directly from the solution itself. The Industrial Revolution in its entirety was a progress trap and created unintended consequences for the environment.

Our next stop on humanity’s production timeline is about 7000 B.C. when nomads were very prevalent in society. They truly lived a sustainable lifestyle in that the majority of their belongings and everyday items, such as camel-skin water containers, were biodegradable²⁴. A nomadic lifestyle allowed them to truly throw “away” unneeded goods which would then decompose and return nutrients to the soil. Nomadic systems are contrary to today’s urban systems in which we believe we are throwing something “away” but it is only being transported to some predetermined location where it sits unnaturally seeping monstrous hybrid substances into the surrounding nature.

As nomadic tribes grew in size they began to settle down and create established farms. The societal-based model, built on hunting, began to evolve into a forging-based model where farmers grew crops to sell and trade. This large change in the current societal model of the time led to the very early beginnings of agricultural industry around 6000 BC. As with hunting, people began to find better and better ways to produce more food through the invention of new techniques and tools, such as irrigation. Food production increased quickly with the population rapidly swelling²⁴. As the initial agricultural model slowly grew in size and started to become an industry, it was increasingly difficult for

farmers to allow plots of land to remain dormant, or lie fallow, as needed to permit nature to take its course and return vitality to the land. As the population grew, the need for grouped living emerged and people began to congregate to well-supplied areas and to form the first established towns which eventually became cities.

There is some debate over when the first cities were established. It is speculated that some of the first cities began to emerge around 4000-3500 B.C., near ancient Mesopotamia, built around the wide Euphrates River²³. These early cities were small enough that the production of goods and food was consistent and still grounded in the traditions of history. Early cities were based around citizens bringing items into the city from surrounding areas for trading, began to create a need to use more local nutrients and resources than could naturally be restored²⁴. This put an unnatural strain on the environment and marks the beginning of the downhill spiral of over consumption we now recognize as damaging.

Up until the Industrial Revolution, populations grew at a fairly constant rate (Figure 2) but as the world population continued to grow, traditional food production was not

Figure 1: World Population Growth

enough and plots of land needed to be constantly fertilized and the ground began to lose its natural vitality.

Innovators began to seek ways to produce food quicker and cheaper which lead to the creation of artificial fertilizers in the nineteenth and early twentieth centuries. Synthetic fertilizers laid the foundation for “massively intensified production of industrialized agriculture”²⁴. To this day, many crops are grown with such chemicals, or are even genetically altered for more productive harvests. Similar to running wooly mammoth herds off of cliffs to increase production, the use of artificial fertilizers was a progress trap that inevitably harmed humanity’s well-being by polluting the environment and marked the beginning of the Agrarian Era, the first milestone of the Industrial Revolution.

To better understand the significance of the Green Revolution and the ongoing efforts for widespread sustainability practices, the specific detrimental conditions and byproducts of the Industrial Revolutions must be realized. Because the Industrial Revolution is such a long and significant event in human history, historians have divided it into two sub-events titled the First and Second Industrial Revolutions which started in 1760 and 1860, respectively. The Industrial Revolution as a whole marks a major turning point in history; almost every aspect of daily life was influenced in some way. Most notably, average income and population began to exhibit unprecedented sustained growth²⁵. The Industrial Revolution was a period of transition to new manufacturing methods which allowed for the mass production of goods. It is unfortunate that during the Industrial Revolution not much thought was given to long-term effects or future generations. As a matter of fact, there was such a strong emphasis on production that even short-term wellbeing was

neglected. The very poor working conditions in factories and mines were completely ignored by the masses for many years²⁶.

The First Industrial Revolution is marked by three major gains in important technologies. Textiles began to be created in bulk using mechanized methods such as cotton spinning machines which were powered by steam or water. Gains were also seen in the weaving of wool and linen. The second major technology gain was the use of steam power to drive engines. These new steam powered engines used one-fifth to one-tenth the fuel and were adapted for rotary motion with made them suitable for industrial and transportation purposes. The last major technology gain of the First Industrial Revolution was increases in iron making. Charcoal was replaced with coke, a product of charcoal, which greatly lowered the cost and allowed for manufacturing in larger blast furnaces leading to economies of scale. Other machines were invented that also increased production such as the rolling mill which was fifteen times faster than previous method of hammering wrought iron by hand²⁷. These key innovations in the major leading sectors of industry at the time boosted the economy and the GDP steadily increased, this increase in GDP actually marks the beginning of the Industrial Revolution.

The Second Industrial Revolution is an extension of the first but corresponding to the latter half of the 19th century until World War I. It is important to separate the two distinct Industrial Revolutions because it is during the Second Industrial Revolution that rapid industrial development occurred in Western Europe as well as the United States and Japan³⁶. This rapid development can be directly correlated to the desperate need for a green revolution which began in the late 1960's and feebly continues to the present. Although many of the major technology gains during the First Industrial Revolution

could be blamed for the needed Environmental Movement later on in the century, it is the Second Industrial Revolution's rapid developments, without strategic future planning that created a need for sustainable action which this thesis discusses.

What is often ignored is that these innovations were seemingly made with a blind eye toward the environment and the human condition, but it must be noted that at the time there was thought to be unlimited resources at society's disposal. The economy was growing in leaps and bounds and the earth was available for development. Fast forward a few hundred years and it is now generally understood that there are boundaries to growth. This created a fight to ingrain sustainable and resilient designs into often called the Green Revolution, or environmental movement: humanity's fight to save the shared planet.

Many believe the Environmental Movement began with the book *Silent Springs* written by Rachael Carson which was originally released in three serialized excerpts in the New Yorker in 1962²⁸. The publishing of the book in September of that year produced a public outcry which halted the use of DDT on Long Island's marshes and brought together many professionals to address the damages that were occurring through the use of agricultural pesticides. These collaborations also spurred revolutionary changes in the laws effecting our land, air, and water. "Many consider the book's release a turning point in our understanding of the interconnections among the environment, the economy and social well-being. Since then, many milestones have marked the journey toward sustainable development"²⁸. Although environmental betterment is a great outcome of increased sustainability concerns, this thesis is not addressing apprehensions about the environment so much as growing industry resiliency. Resilience is achieved by increasing knowledge and communicating a need for quick action which will in turn better the planet as a

whole. As will be seen by delving into the history of the environmental movement, industry has yet to embrace sustainability and resilient designs as necessary for humanity's continued existence, but has instead resisted regulations, always looking for a way around them in focusing on profits. A great example of this can be seen in looking at the lasting changes from *Silent Springs*. A book is written. Everyone talks about it. A few changes are made. Large scale system changes are not.

Silent Springs brought about the creation of the Environmental Defense Fund (EDF) which was founded to pursue legal solutions for the environmental damages which occurred from the spraying of DDT on Long Island's marshes. The Suffolk County Mosquito Control Commission was reprimanded for their use of DDT and further use of DDT was banned. Further direct actions related to the writing of this forward-thinking book did not occur. Hence, the general moral of the story was lost in translation.

In 1968 Paul Ehrlich published *The Population Bomb* which warned people of the direct correlation between the size of the human population, resource exploitation, and the environment. Ehrlich predicted that, by the end of the 20th century, humans would use all available resources; whole areas of human endeavors would screech to a halt due to resource scarcity; England would, in all likelihood, cease to exist; India would collapse due to its inability to feed itself; and inevitable mass starvation would sweep the globe (including the US). Although Ehrlich's timeline proved to be inaccurate, his ideology is not. For many years scientists have repeated the same warning²⁹. Many current economists and ecologists agree that the world's continuous growth model is not only impossible to sustain but must be quickly changed to avoid permanent ecological and social damages³⁰.

Following the writing of *Silent Springs* and *The Population Bomb*, the U.S. government saw a need to pass regulations that would protect the environment and guide citizens toward a brighter future. In 1969 the National Environmental Policy Act was passed in the United States making it one of the first countries to establish a national legislative framework to protect the environment. The law set the basis for environmental impact assessment across the globe²⁸. In 1970, the Natural Resources Defense Council formed as a coalition of lawyers and scientists who together pushed for even more comprehensive U.S. environmental policy than the National Environmental Policy Act was providing. It was evident at this point in history that action needed to be taken and people were willing to band together to make sure that the environment was protected. Our shared planet was finally becoming officially recognized as a common human resource. As if to commemorate the great milestones of the late 1960's, the U.S. celebrated the first Earth Day in 1970 as a national celebration of the environment and an estimated 20 million people participated in peaceful demonstrations across the United States.

In the beginning of the 1960's the concept of environmental preservation and sustainability was left to the radicals and far left lobbyists but by the beginning of the 1970's, people had begun to realize its importance and they were looking to take action. The International Institute for Environment and Development (IIED) was established in 1971 in the United Kingdom to seek ways for countries to make economic progress without destroying the environmental resource base. In the same year the *Founex Report* was prepared in Switzerland by a panel of experts calling for the integration of environment and development strategies. The report noted that while concern about the environment sprang from the production and consumption patterns of the industrialized

world, many of the environmental problems in the world were a result of underdevelopment and poverty.

Although the *Founex Report* is now known to be contrary to current understanding that industry is a main cause in poor ecology, in 1972 the *Founex Report* led many developing countries to attend the United Nations Stockholm Conference on Human Environment which was called for due to the acid rain problems in Northern Europe. Although acid rain was the concerning event at the time, the concept of sustainable development was the main topic of discussion and it was cohesively argued that it presented a satisfactory resolution to the environmental vs. development dilemma which was being heavily debated. The conference led to the establishment of numerous international environmental protection agencies and the United Nations Environment Program (UNEP) but this was all political festivities in the eyes of wary global citizens such as Rene Dubos and Barbara Ward.

Dubos and Ward wrote *Only One Earth*⁵³ to sound an urgent alarm about the impact of human activity and the effect it was taking on the biosphere. They recognized how large changes were needed in the current industry standards if the earth was to be conserved but they also expressed great optimism in a shared concern for the planet and wrote that a common humankind future could be found in seeking out answers together.

In 1972 the Club of Rome published the controversial *Limits to Growth*⁵⁴ which forecast cataclysmic consequences if growth was not slowed down. Although the report was built on three scientists work from MIT using a computer model that analyzed global resource consumption verses production, it was criticized for not pointing toward technological

solutions and for advocating a reduction in economic growth. In 2004, Donella Meadows, the author of *Limits to Growth*⁵⁴, teamed up with Jorgen Randers, and Dennis Meadows to publish a “30 year update”⁵⁵ which provided an updated scenario and a plan of action to reduce our needs to meet the carrying capacity of the planet.

Even after 30 years of alleged sustainable cognizance, the issue of over consumption persists and is even more evident than before with the world population growing beyond 7 billion in 2011. Although consumption is the role of the consumer, industry currently has a unique opportunity to preemptively design products that are made to be upcycled as advocated in *Cradle to Cradle* written by William McDonough and Michael Braungart²⁴. Typical recycling is the devolving of a product into less useful or less desirable elements. This is contrary to upcycling which is when a product is broken into its elements and then those elements are reused for a more desirable or stronger product. If all products were created with a cradle to cradle lifecycle and could be upcycled, consumption wouldn't be a negative thing but rather a productive part of life.

The 1980's brought about many milestones in sustainability starting with the International Union for the Conservation of Nature (IUCN) releasing a report titled “World Conservation Strategy”⁵⁶ which identified the main agents of habitat destruction as poverty, population pressure, social inequity, and trading regimes. The report called for a new international development strategy to redress inequities. The problem with inequality has been debated for a long while but it is evidently very difficult to get the world economies to adequately address inequities.

One inequality the world cannot exist with is disproportion in biodiversity. In an attempt to increase awareness for worldwide biodiversity, the “Global 2000 Report”⁵⁸ was released in 1980 and it emphasized the need for biodiversity because it is a crucial part of a functioning planetary ecosystem. The report asserts that the robust nature of ecosystems is weakened by species extinction.

Another important aspect of sustainability is the social impacts it can have. The World Health Assembly⁵⁹ adamantly emphasized this point in 1981 when they adopted the “Global Strategy for Health for All by the Year 2000”⁵⁷. This position “affirmed that the major social goal of governments should be for all peoples to attain a level of health that would permit them to lead socially and economically productive lives”²⁸.

The main drivers of sustainability can be adequately defined as people, planet, and profit, also known as the Triple Bottom Line. At this point in history the social aspects of sustainability had been discussed as well as the economic aspects, or profit concerns, but the meeting in Austria in 1985 was a milestone for addressing one of the largest negative impacts the planet had faced, and is still facing to this day; global warming. The World Meteorological Society, UNEP, and the International Council of Scientific Unions met and discussed the buildup of carbon dioxide and other greenhouse gases that had become prevalent in the atmosphere. They further predicted global warming.

The meeting in Austria was the beginning of global acknowledgement for the need to preserve the planet. Almost as if to celebrate this achievement and the potential to grow without deprivation, a report titled “Our Common Future”⁶⁰ was released in 1987 which wove together social, economic, cultural, and environmental issues and global solutions.

It officially coined the term “sustainable development” and helped to uncover the possibility of growth without harm.

Five years later, in 1992, the Business Council for Sustainable Development published *Changing Course*⁶¹, a book which established businesses interest in promoting sustainable development. The book is also known for having coined the phrase “eco-efficiency” which refers to the concept of creating more goods and services while using fewer resources and creating less waste and pollution. Eco-efficiency “has been proposed as one of the main tools to promote a transformation from unsustainable development to one of sustainable development” and “is measured as the ratio between the value of what has been produced and the environment impacts of the products or services being produced”³³.

The UN held a Conference on Environment and Development (UNCED) in 1992 in Rio de Janeiro in which three plans were made to address major issues. These plans were called Agenda 21, the Rio Declaration, and the non-binding Forest Principles. Agenda 21 is a global call to action regarding sustainable development and was designed to involve action at the international, national, regional, and local levels. The Rio Declaration was written “with the goal of establishing a new and equitable global partnership through the creation of new levels of cooperation among States, key sectors of societies, and people”

³⁷. “The Forest Principles”, the informal name for the “Non-Legally Binding Authoritative Statement of Principles for a Global Consensus on the Management, Conservation and Sustainable Development of All Types of Forests”⁶², is a document that makes several recommendations for conservation and sustainable development

forestry. These three plans are evidence that legislation is being pushed forward, even at an international scale, which will affect industries everywhere.

During the same Rio de Janeiro conference, two “Rio Conventions” were also opened for signature: the Convention on Biological Diversity and the Framework Convention on Climate Change. The Convention on Biological Diversity was written with the objective of developing strategies for the conservation and sustainable use of biological diversity. It is broken down into three main goals:

1. Conservation of biodiversity
2. Sustainable use of biodiversity and its components
3. Reasonable and equitable sharing of benefits arising from genetic resources

The second convention, the Framework Convention on Climate Change, has the capacity to directly influence industry decisions. This convention was written to help “stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system”³⁸. Although this convention and the one previously discussed do not directly relate to the majority of industry endeavors, they point toward an increase in legislation surrounding the use of resources and developments which will, and does, affect industry standards and methods.

In order to better grasp industry endeavors, the Health of the Planet (HOP) survey⁶³ was coordinated by the George H. Gallup International Institute and conducted by members of the worldwide network of Gallup affiliates. The selection of countries was dependent upon the existence of a Gallup affiliate or willing partner in each country and the availability of adequate funding. Two dozen nations were included, but poorer, less

economically developed nations are underrepresented. The intent, however, was not to conduct a survey whose results could be generalized to the entire world; rather, the goal was to survey citizens in a wide range of nations varied in both geographic location and level of economic development, and thereby go beyond existing multinational surveys that have been limited primarily to Europe and North America. The survey was reasonably successful in this respect, as it covered a greater number and wider range of nations than have ever been included in an environmental survey³⁹.

In moving industry toward sustainable development, the ISO 14001 was created in 1996 as a voluntary international standard for corporate environmental management. Its history can be traced as far back as the 1972 UNEP conference. Shortly following the 1992 Earth Summit, the world's first environmental management systems standard was published by the BSI Group. It was called the BS 7750 and forged the path for a more refined standard, the ISO 14001.

The ISO 14001 focuses on helping organizations minimize how their operations negatively affect the environment while making it easier for them to comply with laws, regulations, and other requirements. As with other ISO standards, audits are performed by a third party. While the ISO 14001 standards help define a framework for an environmental management system, it does not state requirements for environmental performance. It charts a path that companies can follow to create a working environmental management system by providing practical tools that help identify and control environmental impact and continually improve company environmental performance⁴⁰.

Although rigorous compliance to the ISO 14001 standard can result in real improvements, these improvements have been found to be more superficial and administrative in nature⁴¹. The standard in fact has been called a “rational myth” in the context of seeming to create a change within an organization but failing to help that same organization integrate true changes that are beneficial to both the environment and the organization⁴². Olivier Boiral, from Laval University, conducted a case study in which nine companies from varying backgrounds were studied regarding implementation of ISO 14001 standards. It was found that concern for institutional legitimacy was the main driving force behind the initial decision to adopt the ISO 14001 standard⁴¹. It was also found that there were only small changes in environmental practices and performance after implementation, despite the standard’s supposed high level of rigor. This gap between expected change and actual change is often the difference found in managerial statements of expectation and actual practices in implementation⁴³. The creation of the ISO 14001 standards was only the beginning of corporations recognizing the need for a competitive advantage found through applied sustainability.

By 1999, sustainability had become a competitive metric for industry and investors wanted to know which companies were aiming toward sustainable models. The first of its kind, the Dow Jones Sustainability Indexes were created to help investors evaluate profitable companies in terms of their sustainability development principles.

At the end of the decade, despite great steps forward in sustainability, there was still a lot of work to be done in getting industry to fully adopt sustainable thinking in all areas of business and the public was not satisfied with the rate that industry was making changes. During the third World Trade Organization conference, in Seattle at the end of 1999,

thousands of demonstrators protested the negative effects of globalization and the growth of global corporations. This was just the beginning of an era of confrontation between displeased stakeholders and corporations²⁸.

From a sustainable viewpoint, the new millennium started with the modification of the “U.N. Millennium Development Goals” which were agreed upon by many world leaders in order to set time-boundaries and measurable goals for combating poverty, hunger, disease, illiteracy, environmental degradation and discrimination against woman; all to be achieved by 2015²⁸. Since their conception in 1990, the U.N. Millennium Development Goals have been modified multiple times due to missed development milestones. Of the eight goals listed on the UN statistics website, goals seven and eight pertain directly to achieving environmental stability and creating a global partnership for development. These goals are further broken down into targets which were last updated in January 2008. There are four targets per goal and each target has associated indicators used to monitor progress. The four targets for attaining environmental stability are listed as:

1. Integrate the principles of sustainable development into country policies and reverse the loss of environmental resources
2. Decrease biodiversity damage
3. By 2015, halve the proportion of people without access to safe drinking water and basic sanitation
4. By 2020, to have achieved a significant improvement in the lives of at least 100 million slum dwellers

These targets are important for industry to understand because, as stated in target one above, the UN is attempting to integrate various principles into country policies and programs. In understanding these targets, companies can better position themselves strategically for increasing global initiatives and regulations regarding environmental sustainability.

In addition to understanding initiatives in environmental sustainability, it is also important to consider the UN Millennium Goals regarding global partnerships for development, especially for companies looking to become more globally versed. The 4 targets set forth regarding global development are:

1. Develop further an open, rule-based, predictable, non-discriminatory trading and financial system
2. Address the special needs of the least developed countries
3. Address the special needs of landlocked developing countries and small island developing States
4. Deal comprehensively with the debt problems of developing countries through national and international measures in order to make debt sustainable in the long term

The four targets regarding sustainable development are important for companies to keep in mind when considering expansion, especially on a worldwide scale, as legislation becomes more stringent.

In 2002 the World Summit on Sustainability was held in Johannesburg, marking 10 years since UNCED. During the summit, there was much frustration voiced due to the lack of

government progress. In order to push global environmental governance forward, a new type of treaty was created. Unlike a Type I Treaty, which unlike traditional treaties of this type are the more classic outcome of international treaties and requires a full agreement be drawn out, a new type of treaty was created at the World Summit called a type II treaty, or partnership. This allowed for a less formal agreement to be made in which time was saved due to reducing the need for bureaucratic debates.

The next major advance toward global sustainability was the drafting of the Kyoto Protocol⁶⁴ which became effective in 2005, legally binding developed countries to set goals for greenhouse gas emission reductions. The Kyoto Protocol was the first move toward an emissions credit system in which industries can earn and spend a set amount of emissions credits. The ideas behind this system were summed up in the Clean Development Mechanism section of the Kyoto Protocol which defines the flexibility mechanisms through various projects which generate Certified Emission Reduction units. These units can be traded in emissions trading schemes.

Another significant move toward global sustainability occurred when the department store tycoon Wal Mart declared a bold corporate wide sustainability initiative in 2005 which included being supplied by one hundred percent renewable energy, creating zero waste, and selling products that sustain people and the environment²⁸. This corporate strategy began to transform Wal Mart's global supply chain in drastic ways and stood as an example for other international corporations. Because of Wal Mart's influence on the market, and being many of their supplier's largest partners, their suppliers were quick to begin adopting similar sustainability standards to be able to continue relationships with Wal Mart.

With larger industries beginning to take action, the environment was seemingly rewarding. In 2006 NASA announced that the ozone layer had begun recovering as a result of the increases in sustainable practices, especially the reduction in the use of CFCs⁶⁵. Despite all the progress made in the new millennium there were still a lot of sustainability issues to be addressed. But in the same year a paper titled “Stern Review”⁶⁶ was published, “making the convincing economic case that the costs of inaction on climate change will be up to 20 times greater than measures required to address the issue immediately (pg 9)”²⁸.

World food, fuel, and economic crises converged in 2008. Global food prices increased 43 percent in one year and global energy demands also increased extremely rapidly. The U.S. economy faltered due to collapse of mortgage lending. The breakdown of the U.S. economy caused U.S. markets to fail and sent the world into a recession. Following the global recession, many national governments invested a part of their economic stimulus in environmental actions. Low-carbon economy and green growth initiatives became new government-set objectives for the rebuilding of future economies²⁸.

Corporations also realized the need for sustainable action. A survey concerning sustainability, by Accenture and the United Nations Global Compact, was conducted following the Great Recession of 2009 and it received over 775 CEO’s responses. It is interesting to note that the experience of the Great Recession caused many companies to regard sustainability as more important. In fact, 93% of the respondents regard sustainability as important to their company’s success⁴⁴. These survey figures lead to the conclusion that industries are gaining a true interest in sustainability. This conclusion is false.

The Global Compact survey is conducted every few years. Prior to the Great Recession, it was conducted in 2007 and at the time companies were just gaining interest in sustainability as a somber industry matter. Sustainability looked like it was becoming a serious business concern and would be reshaping the rules of competition. Three years later, the 2010 survey seems to reaffirm the growth in sustainable awareness but it must be noted that seventy two percent of survey respondents cite “brand, trust, and reputation” as principal motivators for sustainable efforts⁴⁴. Although sustainability awareness seemed to have grown in the three years between when the two surveys were conducted, the majority of companies still regarded sustainable efforts more as a public relations tactic than a serious part of business growth at the time the 2010 Global Compact survey was conducted. One country to break the norm was China.

China had been focused on its own growth initiatives through the early 2000’s and became the largest domestic market for wind power by 2010, exceeding its own goals for installed capacity by 320 percent. Although wind power continued to expand as the world’s fastest growing renewable energy source, it was still far below target levels set by the Organization for Economic Co-operation and Development (OECD) and emerging economies. The Economics of Ecosystems and Biodiversity final report, released in 2010, called for wider recognition of nature’s contribution to human livelihoods, health, security and culture by decision-makers.

In 2011 the world population reached an astounding 7 billion people. This ever increasing populace is more networked than ever before with 80 percent owning mobile phones and one third having access to the internet. Although networked, and thus potentially easier to inform about sustainable initiatives, the sheer size of the world’s inhabitants make it

difficult to achieve sustainable goals. With the world population having increased by 1 billion in only 12 years, many organizations have been formed to increase awareness about overpopulation. The ever growing populace seems to have no limit and it is very difficult to regain control of ecological systems with an ever increasing need to use resources²⁸.

As the growing world population continued taxing global ecology, China continued to push green initiatives and in 2011 shifted to a green economy model for its 12th five year plan for economic development making a large impact as the nation with the largest populace. This plan was based on sustainable development goals, including substantial reductions in pollution, carbon, and energy intensities. China backed this plan with nearly half a trillion USD in proposed expenditures for environmental protection²⁸.

In 2012, another conference was held called Rio +20. This marked 20 years since Rio de Janiero and fifty years since the publishing of Silent Springs. Rio +20 served as a reconvening of the global community to secure an agreement to attain a sustainable world economy through multiple smart measures for clean energy, better jobs, and more sustainable and fair use of resources. There had been many changes in industry since Rachel Carson wrote her book in 1962, the world has begun to accept the need for increased sustainability, and companies are willing to entertain the idea. The meaning of the word “sustainability” had progressed from the narrow definition of the banning of DDT to a much broader scope of world ecology but is still being defined.

2.2 Defining Sustainability

What is sustainability? According to the Environmental Protection Agency (EPA) it is defined as creating and maintaining the conditions under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic and other requirements of present and future generations. In short, sustainability is the capacity to endure. “It’s not about using as little as we can possibly use, it’s about getting what we need in a sustainable way and that’s what we need to do [for] our systems , is figure out how to get people what they need so that it doesn’t harm the planet”¹⁰. In order to achieve this, industries must realize the impact they have. Corporate sustainability is a business approach that creates long-term shareholder value by embracing opportunities and managing risks deriving from economic, environmental and social developments¹⁹.

Much emphasis gets put on the individual becoming more sustainable and environmentally conscious yet a single business pollutes exponentially more than a single person and thus much more emphasis should to be given to assessing a company’s impact on the environment. It is hoped that when corporations place emphasis on sustainability, individuals will quickly understand the need and follow suit.

In Janine M. Benyus’ book titled *Biomimicry*, she writes that “the Law of Sustainability says renewables should be used at the same rate at which substitutes can be developed (pg 270)”⁹. The pressures to keep pace with growth, anticipate future legislation, recruit from a shrinking labor pool, and spend money wisely during an economic downturn are

driving many companies to reevaluate how they do business¹⁹. “Adopting sustainable alternatives is not only a matter of progress; it’s a matter of survival”¹³. With the condition of Earth’s ecosystems and available resources quickly dwindling, forward-thinking companies are looking into their respective industries to make changes that will help keep their companies ahead of competition as legislation becomes more restrictive.

If there is one adjective to define progressive sustainability it would be the term resilience which describes systems that can survive shock or impact. This concept comes from the field of ecology, the study of the relationships living organisms have with each other. One method of increasing resilience is to build sustainable modularity into a system, or sustainable independence in each facet of business. Another method of building resiliency into a system is to create redundancies which have feedback loops which reinforce the system architecture. The use of these methods will result in a system that is more robust. Sustainability guards against ecological problems but resilient designs can easily handle changes and increase system sustainability. Successful sustainable development requires a systems approach to the design of industrial product and service systems²⁰. Systems without sustainability intertwined into them will eventually collapse.

In the book *Collapse*⁴⁵ written by Jared Diamond, a UCLA Professor of Geology and well know author of *The Third Chimpanzee* (1991), *Guns, Germs, and Steel*(1997), and *The World Until Yesterday* (2012), the dire state of global industry is discussed and compared to past societies that have collapsed. Diamond draws on his education in physiology and from a variety of other fields, including anthropology, ecology, geography, and evolutionary biology to logically explain why past societies have failed,

why globalization has created an interconnected world population, and how this current global population is making the same mistakes as past societies.

Diamond goes further and proposes a roadmap of factors that have contributed to past societal failures that seem to be repeating within the current society. His roadmap divides the factors into a delineated sequence of four categories. The first pitfall is that a group will fail to anticipate a problem before the problem actually arrives. As discussed previously this failure occurred during the Industrial Revolution due to a false analogy that there was never an occurrence of industry destroying ecological facets in the past. The second pitfall is that a society will fail to perceive a problem when a problem does arrive. The most common reason for failure to perceive a problem exists is through slow trending which conceals the problem through large up and down trending cycles.

Fortunately, the slow trend of lack in applied sustainability was shattered by the sustainability awareness that started in the 1960's helped to foster a global acknowledgement of resource depletion. Pitfall three is failure to try to solve the issue after it has been perceived, and pitfall four is that society may try to solve the issue but fail. Since society's recognition of potential global failure due to lack of sustainable activities, there have been many actions taken to help divert global collapse. It is the fourth pitfall that threatens to destroy us. While actions such as reduction, recycling, and reusing of materials are very helpful in prolonging the current consumption model, they do not address the core problem which will eventually result in global failure. It is necessary for industry and society to redesign current processes to be resilient to collapse.

Building a resilient system will not ultimately stop problems from occurring but it will produce a system that can handle changes with ease. Companies that first realize the true

value of resilience in system redesign, and take preemptive action ahead of necessity and legislation, will reap the benefits of inevitability before their competitors. Industry is seemingly far from a fully resilient design. The next section will explore the present state of sustainability in industry and further sections will discuss potential methods of system redesign.

2.3 Industry's Current Place in Sustainability

In order to understand industry's current place in sustainability, it is helpful to quickly revisit some key points in recent history previously discussed in the literature review. The 1992 George Gallup Health of the Planet survey shows that in the early 90's, well over half of companies from twenty-two countries were already avoiding the use of products that harm the environment (pg 246)⁹. In the early 21st century Al Gore stated that the global market for environmental goods was \$300 Billion⁹. Industries have realized the profit potential in creating "green" products but are missing the urgency of necessary system changes. As of the end of the 2012 FY, green investments had grown to a staggering \$4.1 trillion⁴⁷. Any company that hasn't begun to tap this market segment is already falling behind.

Businesses change when the public demands it. Changes in public attitude toward environmental issues are essential for changes in business environmental practices⁴⁵ but there are bound to be "clashes of interest involving rational behavior when the principle consumer has no long-term stake in preserving the resource but society as a whole does (pg 430)"⁴⁵. Since the end of the Industrial Revolution, when industries needed to be controlled because of their destructive nature, focus has always been on reducing,

avoiding, and minimizing the “bad”. There is no more time to just “reduce”. Industry’s standards of production need to be reshaped.

Changing a habit is difficult. Companies have created habits, or methods, that are not sustainable but they refuse to change these methods because it is not demanded by governments or consumers. In short, these companies are risk adverse, performing only at minimum required standards and avoiding change. In a book by Malcolm Gladwell titled *Blowing Up*, the psychology of risk aversion is explained through a simple scientific experiment.

In a study done by Kahneman and Tversky a group of people were told to imagine that they had three hundred dollars. They were then given a choice between (a) receiving another hundred dollars or (b) tossing a coin so that if they won they got two hundred dollars and if they lost they got nothing. Most of us, it turns out, prefer (a) to (b). But then Kahneman and Tversky did a second experiment. They told people to imagine that they had five hundred dollars, and then asked them if they would rather (c) give up a hundred dollars or (d) toss a coin and pay two hundred dollars if they lost and nothing at all if they won. Most of us now prefer (d) to (c). From a probabilistic standpoint, those four choices are identical: they all yield an expected outcome of four hundred dollars. Nonetheless, we have strong preferences among them. Why? Because we’re more willing to gamble when it comes to losses, but are risk averse when it comes to gains¹⁶.

If the need to become resilient can be portrayed to industry as a way to avoid losses rather than a potential for gains, then perhaps industry will behave in a personified way and choose to “gamble” against sure losses.

Companies tend to cautiously approach green initiatives, carefully calculating return on investment and only pursuing initiatives that produce short-term profit ¹⁴. As companies begin to realize that implementing sustainability in all areas of business is not an offensive move forward to increase short-term profits but indeed a defensive strategy to stay risk adverse and solidify long-term revenue, they will be more open to making changes to favor sustainable practices.

“Many businesses model their definition of sustainability after the concept of the triple bottom line – pursuing performance in economic, social, and environmental spheres – or, more generally, after common definitions such as that contained in the 1987 Brundtland Commission report, “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs” ². The Triple Bottom Line (TBL) is a tool used by many companies to assess the noteworthiness of any possible green initiatives at their respective companies and is defined as the consideration of people, planet, and profit in making business decisions ¹⁰ but as was found in a large sustainability survey by Deloitte, the issues associated with using the triple bottom line as a decision rule is that many times the social component of the TBL is lost in the focus on environment sustainability (page 3) ².

All aspects of the TBL are acknowledged when industry’s standard changes from being “apart” from nature to “a part” of nature and the surrounding ecosystems. This needed

shift from “aiming to increase prediction, control, and manipulation *of* nature as a resource to a transdisciplinary cooperation in the process of learning how to participate appropriately and sustainability *in* nature”¹² “is much needed and will require methods of change which are carefully thought through and systematically implemented. The TBL is a small example of the many tools that can lead toward increased system sustainability.

With entropy and complexity ever increasing in the known universe, systems-thinking is becoming more and more critical to help manage, adapt, and understand the multiplicity of choices available to combat waste²⁰. “Because of feedback delays within most complex systems, by the time a problem becomes apparent, it may be unnecessarily difficult to solve”²⁰. A diverse system with many pathways and redundancies is more stable and less vulnerable to external shock than a uniform system with little diversity²⁰. Natural systems have survived the test of time and have thus solidified systems which have built in feedback loops which quickly alert the containing system of failure.

Resilience arises from a rich structure of many feedback loops that can work in different ways to restore a system even after a large perturbation. A single balancing loop brings a system back to its desired state. Resilience is provided by such loops, operating through different mechanisms at different time scales, and with redundancy-one kicking in if another fails²⁰.

Nature is by definition extremely resilient which is why it has survived the test of time. The next section will investigate how nature has been replicated by humans, the emerging field of biomimicry, and how industry can identify potential biomimicry opportunities.

2.4 Biomimicry

Many times the “highest” achievement, or Mecca, of sustainability is to achieve “net zero” impact; resources in equal resources out. Nature goes one step further and creates systems which are not only “net zero” but are beneficial to everything around them ⁸. Steve Jobs once said, “I think the biggest innovations of the 21st century will be at the intersection of biology and technology. A new era is beginning.”

In an attempt to capture the way nature designs systems and how humanity can mimic them, the term Biomimicry was coined by Janine Benyus in her book, *Biomimicry*, written in 1997. In her book, Janine covers a multitude of successful biomimicry examples and prompts the reader to consider how nature can provide solutions to their problems. Although written without much technical explanation, *Biomimicry* helped to raise awareness regarding the solutions nature can provide and inspired many productive projects and creative outlets such as the Biomimicry Institute, Biomimicry 3.8, and the Biomimicry Guild; all facets to help inspire design from nature.

The technique of studying nature’s best ideas and then imitating its designs and processes to solve human problems is not a new method. Biomimicry has been used throughout history. In fact, the beginning of applied biomimicry could be argued to be the first time *Netherlands* created fur coverings to mimic the animals around them. Another prime example of biomimicry is the invention of Velcro by George de Mestral in 1967 in which cockle burs were mimicked using plastic to replicate the tiny loops and hooks that are very adhesive when joined together. Other examples of biomimicry include the mimicking of termite mounds to design self-cooling buildings, lotus leaves to design self-cleaning paint, and the King Fisher in designing the Bullet Train³. All of these simple

designs use inspiration from a single entity in nature. The level of ingenuity is exponential when looking at entire systems of interworking entities.

Biomimicry is fostering multiple variations of innovation. Ecosystems prove a great inspiration to design. They are very resistant to dilapidation, with several species balancing each other out through time and climate change. Populations within ecosystems have the ability to learn and evolve through their incredibly rich genetic variability. And given enough time, they will come up with a whole new system to take advantage of changing opportunities²⁰. A few forward-thinking businesses have recognized the opportunity to borrow from nature's wisdom and remodel themselves after the most thoroughly tested life-supporting process in existence; nature itself¹⁴.

A complex example of systems thinking inspired by biomimicry is the use of honeybee hive behavior in the mapping of internet servers. Sunil Nakrani and Craig Tovey at Georgia Tech have created an algorithm based on hive behavior which can be used in managing server allocations because "server allocation closely resembles honeybee foraging allocation amongst flower patches (pg 1)"⁶.

Looking to nature, Janine Benyus explores a paradigm of business types can be seen in forest ecosystems. Specifically looking at three types woody plants:

Type I are the opportunists (weeds, microbes, etc.). They take advantage of natural resources, quickly using them up and then withering away when all the resources are gone. Type II plants are the perennial bushes and woody seedlings. These plants grow their roots a little deeper but are still affected by the amount of natural resources available. Masters of efficiency, Type III species don't need to

look for sunlight because they live in synergy with the species around them and put their energy into optimizing these relationships (pg 258)⁹.

Although mimicking nature is not a new method, looking to nature for inspiration in designing, or redesigning, a system to eliminate waste is very much a new idea. As nature exemplifies and Steve Jobs recognized, it is advantageous for businesses to begin to consider moving beyond the standard remedial sustainability actions and explore how their business strategy can incorporate a synergetic bio-inspired plan that can help make a business ahead of competition and profitable. Applying sustainability from a systems perspective can foster advances through applied resiliency.

2.5 Toolsets

The culmination of this thesis is the designing of a framework that provides a simple yet effective way for industry to evaluate the current state of a system and then take decisive action to improve that system's overall resilience. This section will outline the types of tools available, introduce various well-known sustainability tools, summarize the pros and cons of each, and conclude with a summary of necessary benefits the new framework would provide.

There are several types of sustainability tools available which fall into three different categories. The first category is transition strategies. These are strategies which foster the early transition stages of sustainable action taken at a company such as recycling programs and the use of more eco-friendly materials. Transition strategies tend to be superficial and lack the deep reaching changes the other two categories can provide¹⁴. The second category, dubbed mid-level analysis tools, involves benchmarking using established or newly defined metrics. These metrics can be used to develop action plans

to increase the resilience of a company but generally are used to increase the public image of a company and used to boast a green concern for product development¹⁴. The last category is deep system change tools. These changes are brought about through generally complex tools which assess every area of possible sustainable interconnectivity. This thesis will focus on the second and third categories of sustainability tools leaving out the first due to its lack of resulting system changes.

Mid-level Sustainability Analysis Tools

Mid-level sustainability analysis tools can help to gain an understanding of industry benchmarking; corporate sustainability reporting is a method which involves mining company information about economic, environmental, social, and governance performance. Corporate sustainability reporting is a fairly recent trend which has expanded over the last twenty years. Generally, companies produce an annual sustainability report containing many rating and standards in the form of key drivers taken from the guidelines set by the Global Reporting Initiative (GRI). The GRI Sustainability Reporting Guidelines enable all organizations worldwide to assess their sustainability performance⁵⁰. According to GRI, the steps to creating a thorough and comprehensive report can be summarized by Figure 3.

Figure 3: Defining Sustainability Report Content⁵⁰

The first step in creating a report is identifying the sustainable context in which the company can assess progress and create benchmarks. The aim is to create a shortlist of topics that should be assessed.

The second step is prioritization. In this step all identified topics are evaluated for relevancy and how much coverage they should be afforded. Each potential topic should be assessed in regards to the significance to both the stakeholders and the company. The effectiveness of the report is determined in this step so careful consideration and thoughtfulness should be provided.

Validation is the last step of creating a sustainability report. In this step all material topics set forth in the previous two steps must be validated against the reporting principles defined by the company. The scope of the report, boundaries set by the company, and time allowed for reporting must be considered during validation.

Sustainability reporting requires a case-by-case method which often requires an ad hoc tactic leading to reports that are individual to each company. Sustainability reporting can result in system changes if careful consideration is taken when developing the subsequent metrics and related standards.

The last metric tool investigated in this section is Life Cycle Assessment (LCA). The LCA tool spans the gap between metric tools and system change tools because it tends to be simple to use like other metric tools and can greatly foster system changes if used appropriately. Life Cycle Assessment is a method of analyzing the environmental impact of products through all stages of development from raw materials sourcing to disposal/reuse (Figure 4)⁵¹.

Figure 4: Life Cycle

The purpose of the LCA tool is to not only assess the ecological demands of product development but to raise questions concerning all steps of the life cycle. Some specific example questions that may be raised in each step of the life cycle are listed below⁵¹.

Raw Materials

- What raw materials go into the creation of this product?
- How and where are they harvested?

Manufacturing

- How is the product manufactured?
- What types of fuels are used to supply the plant?
- Are the employees treated fairly?
- Are there any carcinogens in the product?

Manufacturing Waste

- Where does the waste from the manufacturing process go?
- Can the waste be reused?

Transportation

- How far does the product have to travel?
- How is the product transported to the customer?
- Are the most sustainable transportation methods used?

Installation

- What goes into the installation of the material?
- Do you need additional elements like mastic or a vapor barrier? If so, you might need to look into the life cycle of those elements as well.

Use

- How is the material used?
- Is it durable?
- What is the typical lifespan?
- What can be done to extend the lifespan?

Maintenance

- Are there chemicals needed to maintain this product?

Disposal/ Repurposing/Reuse

- How do you dispose of the product?
- Can it be reused or repurposed?
- Is it recyclable?
- Does the manufacturer take the product back?

Life Cycle Assessment consists of four minor stages and five major stages. The minor stages are defined as goal and scope definition, inventory analysis, impact assessment, and improvement analysis/interpretation (Figure 5)⁵². Each stage of the assessment requires constant interpretation in regards to company goals.

Figure 5: LCA Framework

The major stages of the LCA are raw material acquisition, materials manufacture, production, use/reuse/maintenance, and waste management (Figure 6)⁵².

Figure 6: Inputs and Outputs of LCA

The LCA tool can be a great conduit to discovery and is simple enough for first time sustainability advocates to use. The next category of tools requires a much deeper understanding of system processes.

Sustainability System Change Tools

The second category of sustainability tools investigated in this thesis are the deep system change tools that are generally more complex and time consuming but which gain much better results. Revisiting the example of different business types discussed in the book Biomimicry, Type III plants are masters of sustainability because they follow a few simple guidelines that Benyus outlines in ten steps:

1. Use waste as a resource
2. Diversify and cooperate to fully use the habitat
3. Gather and use energy efficiently
4. Optimize rather than maximize
5. Use materials sparingly
6. Don't foul their local environment
7. Don't deplete resources
8. Remain in balance with the biosphere
9. Run on information
10. Use local materials

These ten steps allow the type III plants to coexist with their environments while growing and nurturing themselves. These steps provide a framework that can be used to understand the system efficiencies and benefits so prevalent in nature. From a systems point of view, these steps can be seen as an opportunity for directly applying biomimicry.

A thesis titled “The Integration of Biomimicry into a Built Environment Design Process Model”⁴ describes a methodology, called Life’s Principles, for discovering possible applications of biomimicry in a system. These “Life’s Principles” are a set of principles which serve as design blueprints for all of life. Using these principles, or steps, can help to identify potential biomimic areas of business:

1. Selection Criteria
2. Identifiable patterns
3. Emulate patterns
4. Evaluate

“A biologically inspired solution to a problem is appropriate when the essential difficulty of the problem is similar to the challenge in the biological system (pg 195)”⁷. The biomimicry identification steps discussed above can be helpful in migrating current systems toward a more sustainable model.

Shifting attention toward more generally applied sustainability tools, Circles of Sustainability is a tool which can help foster an investigation into all areas of a dynamic project or established process. This tool has been designed and used to help create more sustainable cities. It was designed by The Global Compact and is heavily influenced by

U.N. initiatives and thus maintains a globally understandable and generally simple characteristic⁴⁸.

Circles of Sustainability is a tool which offers a simple graphic, in the form of a circle with four main sections, which serves as the main method of application. Each section represents one of the four main aspects of system sustainability defined as economics, ecology, politics, and culture. The graphic is easily explained in two levels. The first level is an indication of satisfaction based on the number of smaller diameter circles filled in. The second level further defines the four main sections by splitting each into seven subsections. Thus there are a total of 28 pieces which make up the entire circle. The following graphic, Figure 7, explains application of this tool in more depth.

Figure 7: Circles of Sustainability Diagram⁴⁸

As an example of what the Circles of Sustainability looks like in action, the following figure, Figure 8, shows each level being used. The example further defines each subsection satisfaction level by creating nine inner circles and differentiating by color.

CIRCLES OF SUSTAINABILITY

Figure 8: Circles of Sustainability Example⁴⁸

The Circles of Sustainability tool offers a simple graphical and qualitative way to assess 28 factors which play a role in overall system sustainability. Because it was designed to highlight the social aspects of city design, it does not offer the level of detail necessary for seeing quantitative change in an industrial setting. The main issue with this tool is the lack of a methodology leading to over simplification. Although not quantitative, Circles of Sustainability does foster high levels of interconnectivity and will provide a benchmark for unparalleled simplicity and connectivity in creating a framework for change.

Another well-known sustainability tool is the Environmental Performance Index (EPI). Created to supplement the environmental goals discussed in the U.N. Millennium Development Goals, this method of quantifying and numerically benchmarking the environmental performance of a country's policies helps assess all areas of potential sustainability factors. A successor of the Environmental Sustainability Index (ESI), also developed by Yale University, the Environmental Performance Index builds upon the ESI by offering outcome-oriented indicators that can easily be used to create a benchmark index. The EPI is divided into two main sections and then multiple subsections, each with their own indicators of sustainability (Figure 9).

OBJECTIVE	ENVIRONMENTAL HEALTH		
POLICY CATEGORIES	Environmental Burden of Disease	Water (effects on humans)	Air Pollution (effects on humans)
INDICATORS	1. Environmental Burden of Disease	2. Adequate Sanitation	4. Indoor Air Pollution
		3. Drinking Water	5. Urban Particulates
			6. Local Ozone
OBJECTIVE	ECOSYSTEM VITALITY		
POLICY CATEGORIES	Air Pollution (effects on ecosystems)	Water	Biodiversity and Habitat
INDICATORS	7. Regional Ozone	9. Water Quality Index	11. Conservation Risk Index
	8. Sulfur Dioxide Emissions	10. Water Stress	12. Effective Conservation
			13. Critical Habitat Protection
			14. Marine Protected Areas
POLICY CATEGORIES	Productive Natural Resources	Productive Natural Resources	Productive Natural Resources
POLICY SUB-CATEGORY	Forestry	Fisheries	Agriculture
INDICATORS	15. Growing Stock	16. Marine Trophic Index	18. Irrigation Stress
		17. Trawling Intensity	19. Agricultural Subsidies
			20. Intensive Cropland
			21. Burnt Land Area
			22. Pesticide Regulation
POLICY CATEGORIES	Climate Change		
INDICATORS	23. Emissions per capita		
	24. Emissions per electricity generated		
	25. Industrial carbon intensity		

Figure 9: Environmental Performance Index (2008)⁴⁹

The EPI is very thorough in covering the majority of categories integrated within system sustainability at a very macro level and it also fosters interconnectivity and is relatively internationally understandable. The major drawback is the high level of complexity in both assessment and judgment. Not only does it require large amounts of know-how and time to look at all the indicators but it is designed for large systems such as whole countries that deal with many facets of potential sustainability effects⁴⁹.

In conclusion, there are many types of tools and methodologies available for increasing the sustainability of companies and the systems they use. In this section three types of tools were reviewed: methodology tools which provide a series of steps for attaining high levels of sustainability, benchmarking tools which allow a company to assess their current levels of sustainability and use the results to push for increased efforts, and identifier tools which qualitatively identify what areas of a system are lacking. To briefly summarize the research found on these types of tools and their individual aspects, a summary table was created (Table 1).

Name	Category	Type	Pros	Cons
Sustainability Reporting	Mid-level	Methodology	<ul style="list-style-type: none"> ·Mediocrely simple ·Quantitative ·Detailed 	<ul style="list-style-type: none"> ·Doesn't foster interconnectivity ·Susceptible to subjectivity
Life Cycle Assessment	Mid-level	Benchmarking	<ul style="list-style-type: none"> ·Quantitative ·Very detailed ·Fosters interconnectivity ·Graphical 	<ul style="list-style-type: none"> ·Not simple ·Requires significant amount of time
Life's Principles	Deep System	Methodology	<ul style="list-style-type: none"> ·Simple ·Qualitative 	<ul style="list-style-type: none"> ·Not detailed enough
Circles of Sustainability	Deep System	Identifier	<ul style="list-style-type: none"> ·Mediocrely simple ·Qualitative ·Highly fosters interconnectivity ·Graphical 	<ul style="list-style-type: none"> ·Lacks details ·Needs accentuating methodology
Environmental Performance Index	Deep System	Benchmarking	<ul style="list-style-type: none"> ·Quantitative ·Very detailed ·Fosters interconnectivity 	<ul style="list-style-type: none"> ·Very complex ·Cannot be used for small systems

Table 1: Sustainability Tool Comparison

The next section of this thesis will discuss the methodology of determining exactly what industry needs in a framework to help achieve more biocentric and sustainable systems.

Chapter 3: Methodology

The following chapter describes the logical procedures used in realizing industry's current sustainability state and the steps taken in creating a generalized framework, which can help greatly increase a system's resilience.

1. Define root cause behind unsustainable practices in industry by conducting a literature review
 - a. Summarize the history of sustainability
 - b. Investigate current best practices and define relevant sustainable practices
2. Summary of research leading to the creation of a survey to uncover current sustainable methods and industry mindset regarding sustainability
3. Create and distribute survey
4. Analyze survey results and draw conclusions to identify main areas that need to be addressed during the designing of a framework
5. Design framework for general industry use to help uncover opportunities to increase sustainable practices and increase resiliency
6. Summarize and define the "Reshaping Industry Sustainability Efforts" (RISE) framework

3.1 Summarizing the History of Sustainability

The first step toward realizing industry's current state of sustainability and best practices is to establish the foundation on which current sustainable measures have been built. In this manner, the development of a high quality survey to discover the current sustainable activities in industry can be achieved.

A large portion of the literature review in this manuscript is dedicated to establishing a strong foundation of early historical events and the cultural context, which led to unsustainable industry practices. By investigating these topics, a framework which addresses deep-rooted unsustainable practices can be carefully constructed.

Sustainability is defined above, in section 2.2, but a more relevant and current definition must be discovered in order to design the most applicable framework for current use in industry. The creation of a survey to discover the current sustainable mindset and the analysis of the responses are described below.

3.2 Best Practices

It is interesting to see how the best practices in industry sustainability lead toward a more resilient system. A study titled “Keys to Sustainability Leadership: Five Best Practices”⁴⁶ nicely summarizes the top attributes that make a company more sustainable. The study was conducted by Brand Logic and involved 31 leading companies representing over \$2.8 trillion in market capital. According to the study the five best practices to attaining a sustainable business are⁴⁶

1. Integrating sustainability into the business strategy
2. Taking responsibility for the impact of internal operations
3. Companywide understanding of standards and full transparency
4. Integration into brand and client value propositions
5. Operational initiatives tie back to core business values

These best practices will be reflected in designing a survey to assess the current state of industry sustainability by including a question that requires respondents to rank a list of

sustainability statements from most to least sustainable. Ranking will create a way to evaluate the level of sustainable integration each participant's related company has achieved.

3.3 Designing the Current Activities Survey (CAS)

Much thought was put into creating the CAS. The initial step was to decide how to best design a survey that would be concise yet solicit the right information. In considering how to best design the survey questions, length, wording, and logical flow of the questions were all considered⁶⁴.

The initial CAS design had the majority of questions posed as short answer prompts but it was decided that the survey should be restructured into three main segments. The first segment was created as an introductory segment, only asking respondents basic questions such as where they work and what type of work they do. The second segment is the largest section and requires the participant to answer several questions regarding sustainability at the company where they work and from a personal level. The third and last segment is composed of open-ended questions and prompts the respondent to give deeper answers than can be acquired in the second segment. All of these segments compose the concise CAS survey which was used to gain a most relevant data sample of industry.

3.4 Distributing the Current Activities Survey (CAS)

The survey was created to gather current business perspective on sustainability for the purpose of gauging a benchmark. This benchmark will be most useful for developing and tracking changes in sustainable practices over time. As is typical for survey questions,

they were carefully articulated to be both non-leading and allow room for the respondent's non biased answer. The survey can be found in Appendix A.

In designing the survey, the first step was to brainstorm an exhaustive list of questions. By creating an exhaustive list, it was much easier to select the best questions which would prompt significant responses while reducing the length of the survey. Several question types were considered including quantitative, open ended, Likert scale, qualitative, etc. It was decided that keeping the survey as concise and simple as possible would yield the highest response rate with the most efficient answers. Prototype testing was performed with several individuals to best revise the survey and perfect the wording.

The survey was designed with three general categories of questions: background, definition, and open-ended. The first several questions (Question 1, 2, and 3) help to establish which industry sector the participant is representing. It was hypothesized that there may be differences in sustainable practices across industries. The second set of questions (questions 4 and 5) helped to gain an awareness of how the participant and company view sustainability. Lastly, the third group (questions 6, 7, 8, 9 and 10) delve deeper into what sustainable actions the company has taken and what actions the participant believes the company can take to become more sustainable. A final question was included to assess whether the participant feels that a new and improved framework is needed to help further sustainability in industry, specifically in their company.

Because uncovering emergent sustainable practices was the main goal, it was thought best to survey companies who most likely have given their attention to these matters. It was decided that due to its size and awareness in the sustainable space the Central Coast

of California served as an ideal area to gather the sample of companies for survey distribution. Although not random and thus not statistically sound, it was felt that the information would be most useful if gathered from known advocates of sustainability and Cal Poly supporters. A variety of industries sectors were sent the CAS including aerospace, semiconductor, medical, tech, agricultural, apparel, and food. Contact information for 39 local businesses was collected and a personal email was written to each with a link to the CAS. These local businesses are all highly integrated with Cal Poly through past projects and mentorship thus pre-establishing their willingness to participate with the university. A summary of the respondents can be seen in Table 2.

Size	Location	Product Type	Market Segment
Mid	San Luis Obispo	metals	Tech
Small	San Luis Obispo	consumer goods	Sports
Small	Santa Maria	organic	Chemical
Mid	Santa Maria	plastics	Biomedical
Small	Mountain View	metals	Construction
Mid	San Luis Obispo	metals	Tech
Mid	Ventura	plastics	Aerospace
Small	Global	paper	Creative
Large	Paso Robles	metals	Construction
Small	Arroyo Grande	organic	Agriculture
Mid	Santa Maria	metals	Energy
Small	San Luis Obispo	paper	Education
Small	Santa Maria	metals	Home goods
Large	Oxnard	metals	Manufacturing
Large	Santa Maria	metals	Construction
Small	Santa Maria	plastics	Consumer goods
Small	San Luis Obispo	metals	Automotive
Large	Palo Alto	information	Tech
Small	Santa Barbara	metals	Energy
Small	San Luis Obispo	plastics	Health
Mid	San Luis Obispo	information	Manufacturing

Table 2: CAS Respondents Summary

The size of the company is determined by small (<100 employees), mid (100-300 employees), and large (>300 employees). The location, product type, and market segment

are all provided in an anonymous fashion to create a general summary of what type of companies responded to CAS.

Of the thirty nine contacts, there were twenty five respondents representing twenty-two different companies. This is a respectable response rate of approximately sixty four percent. This high response rate in itself reflects the awareness of sustainability for companies on the Central Coast of California. Respondents vary in title but include a large number of presidents, operations managers, and head engineers. Represented companies handle different types of materials such as metal, plastic, bio-material, information, and other materials handling. Four of the twenty two companies handle more than one type of material.

Type of Material	Respondent Count	Percentage
Metals	14	50%
Plastics	8	29%
Information	2	7%
Bio-material	2	7%
Other	2	7%

Table 3: CAS Survey Respondent Diversification

Figure 10: CAS Survey Respondent Diversification

In discovering how respondents viewed sustainability, a ranking question was formulated (Appendix A, Question #4). Respondents were instructed to order the statements from 1 to 7 in order of decreasing importance. This question was formulated to determine which statements the respondents associated most closely with sustainability.

The statements in this question are based on research regarding systems thinking and sustainability. Simple statements like “recycling of materials” is a very low level impact item in a sustainable system, whereas “minimizing negative impacts” can incorporate many practices and may be a guiding vision for resilient enterprises. The order of ranking as discovered in the literature that best defines sustainability in terms of single statement is shown in Table 3.

Sustainability Statement	Official Ranking
Minimizing negative impact	1
Building of resilient systems	2
Act of becoming a positive attribute to the environment	3
Decreasing of waste	4
Redesigning of current industry techniques	5
Creating of earth-friendly products	6
Recycling of Materials	7

Table 4 : CAS Official Individual Statement Ranking

In evaluating the responses, they were found to highly vary. Looking at the means and standard deviations for each response in **Error! Reference source not found.** helps see the variations.

Sustainability Statement	Calculated Mean	Std. Dev.
Decreasing of waste	2.6	1.28
Minimizing negative impact	3.3	2.27
Recycling of Materials	4.1	2.01
Building of resilient systems	4.3	2.07
Act of becoming a positive attribute to the environment	4.3	1.42
Redesigning of current industry techniques	4.5	2.14
Creating of earth-friendly products	5.1	1.8

Table 5: CAS Individual Sustainability Statement Ranking

In attempting to better understand the variations in response to question #4, a bar chart was created which displays both the mean and std. dev. for each statement (Figure 11).

Figure 11: CAS Individual Sustainability Statement Rankings

Figure 11 seems to show that the general conflict in answers between respondents is uniform across all answers (std. dev. $\sim \pm 2$). Using Minitab student edition to analyze the responses, a Kruskal-Wallis Test on Response was generated. This is a non-parametric test often used for survey ranking questions (Table 6).

Kruskal-Wallis Test: Response versus Question

Kruskal-Wallis Test on Response

Question	N	Median	Ave Rank	Z
1	20	2.500	55.5	-1.79
2	20	5.000	75.5	0.60
3	20	4.000	76.5	0.71
4	20	2.000	41.5	-3.45
5	20	5.000	80.5	1.19
6	20	6.000	92.5	2.62
7	20	4.000	71.5	0.12
Overall	140		70.5	

H = 20.81 DF = 6 P = 0.002

H = 21.25 DF = 6 P = 0.002 (adjusted for ties)

Table 6: ANOVA CAS Question #4

Using a 95% confidence interval, the small p-value (<0.05) indicates that it is unlikely that the differences observed are due to random sampling. Furthermore, at least one of the statement means in CAS Question #4 differs from the rest. A Tukey test was conducted to determine which mean(s) differed from the rest.

Using the Tukey Method to create a table (Table 7), CAS Question #4 statements can be grouped by according to related means.

Grouping Information Using Tukey Method

Question	N	Mean	Grouping
6	20	5.100	A
5	20	4.500	A B
3	20	4.300	A B C
2	20	4.250	A B C
7	20	4.050	A B C
1	20	3.250	B C
4	20	2.550	C

Means that do not share a letter are significantly different.

Table 7: Tukey Method CAS Question #4

According to the Tukey Method, using the official ranking of statements as seen in **Error! eference source not found.**, the sixth statement in CAS Question #4 varies from statements one and four. It can also be seen that statement four differs from statement five. The Tukey Method thus shows that respondents statistically deemed creating earth friendly products as significantly less important than minimizing negative impact and reducing waste. Respondents also ranked redesigning of current industry techniques as less significant than reducing waste. These rankings are in line with the official ranking of the statements but there still remains a lot of confusion concerning the majority of statements.

In order to practice high-impact interventions that result in long lasting and deep rooted sustainability and resilience, a comprehensive understanding of the meaning of sustainability is necessary. The responses gathered for this survey question indicate a basic understanding of certain statement rankings but there is a need for increased individual awareness regarding sustainability and the impact of particular policies. Because the sum of each individual in a company defines the industrial heartbeat of the company, individual viewpoints on sustainability greatly affect the summed view on sustainability.

Another question of interest on the CAS (Appendix, Question #5) was created to gain an understanding of how respondents felt the companies where they work view sustainability. A Likert scale was used to assign values to each statement: strongly disagree, disagree, neither agree nor disagree, agree, and strongly agree. Unlike the previous survey question, this question requires a case by case study per statement. There were eight statements concerning company sustainability made in this question (i.e. the company where I work...):

1. Is flexible to changes
2. Reacts quickly to economic changes
3. Is sustainable
4. Believes it is important to build sustainability into the business
5. Sets sustainability as a top priority for the company
6. Would be willing to interact with other businesses to become more sustainable
7. Sees social aspects of the business as part of sustainability (e.g. societal impacts, employee wellbeing, etc.)
8. Has independent business units that can function separate from each other

Survey data for this question is shown in the two bar graphs below. Figure 12 shows the number of individual responses per question giving a visual summary of how each statement was valued by the respondents.

Figure 12: CAS Company Sustainability Per Question

To create a quantitative summary of CAS question #5 values were assigned to each of the typical five Likert scale responses (Table 8).

Response	Value
Strongly Disagree	1
Disagree	2
Neither Agree Nor Disagree	3
Agree	4
Strongly Agree	5

Table 8: CAS Question #5 Likert Scale Values

Calculating the average product for each of the statements creates a metric which can be used to assess the level of importance respondents assign to each statement. Figure 13 shows the calculated averages for each statement to be relatively equal thus indicating that respondents feel that the companies where they work value sustainability and are currently working on increasing company sustainability.

Figure 13: CAS Question #5 Likert Scale Averages

From these results, it can be concluded that a majority of respondents agree with, or strongly agree with, the sustainable-based statements regarding the companies where they work. Looking further into the statistical significance of these responses, a repeated measure one-way ANOVA was conducted using Minitab.

Analysis of Variance for Response, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Question	7	20.7524	20.7524	2.9646	3.38	0.002
Error	152	133.2570	133.2570	0.8767		
Total	159	154.0094				

S = 0.936318 R-Sq = 13.47% R-Sq(adj) = 9.49%

Table 9: ANOVA CAS Question #5

As with CAS Question #4, the small p-value infers that at least one of the means differs from the rest.

Grouping Information Using Tukey Method

Question	N	Mean	Grouping
1	20	4.3080	A
2	20	4.0560	A B
4	20	4.0000	A B
7	20	3.8500	A B
6	20	3.8000	A B
3	20	3.7370	A B
8	20	3.3000	B
5	20	3.1500	B

Means that do not share a letter are significantly different.

Table 10: Tukey Method CAS Question #5

As seen in Table 10, the mean for question 1, “the company where I work is flexible to changes”, is significantly higher than the means in questions five and eight, “sets sustainability as a top priority” and “has independent business units”, respectively. These results again reiterate that companies, according to their employees, are willing to change but do not understand the urgency of becoming sustainable, let alone resilient. Employees feel that the companies where they work are sustainably minded but, on average, agree that companies are not setting sustainability as a top priority.

Creating a basic pie chart shows the large amount of agreement given for each statement. These results indicate that surveyed industry members overwhelmingly agree that the companies where they work are sustainable according to these statements.

Figure 14: CAS Company Sustainability Summary

The most interest in CAS Question #5 lies in the disagreement. Looking for gaps in current practice we looked at the statements where the companies answered either “disagree” or “strongly disagree.” It is interesting to note the statements with which respondents disagreed most. The following list is sorted by most disagreement to least, with strong disagreement counting twice that of disagreement:

1. Sets sustainability as a top priority for the company (35% disagreement)
2. Has independent business units that can function separate from each other(35% disagreement)
3. Believes it is important to build sustainability into the business (10% disagreement)
4. Sees social aspects of the business as part of sustainability (e.g. societal impacts, employee wellbeing, etc.) (10% disagreement)
5. Reacts quickly to economic changes(6% disagreement)
6. Is sustainable (5% disagreement)
7. Would be willing to interact with other businesses to become more sustainable (5% disagreement)
8. Is flexible to changes (0% disagreement)

Given that the literature identifies these best practices and that a large percentage of companies in this progressive area of California identify the lack of focus on sustainable practices, it is logical to conclude there is much room for improvement in knowledge or

implementation of resilient methods. This is contrary to the Deloitte Sustainability Survey¹ and the United Nations/Accenture CEO Study⁴⁴ which stated sustainability as being a top priority for the large majority of businesses. It can be hypothesized that the stark difference between other survey results and the survey results collected for this thesis are due to the differences in company size. The majority of surveyed companies for this thesis are small to medium size companies whereas the companies surveyed by Deloitte and the UN are Fortune listed companies. Regardless of the reason, conveying the need for sustainable practices, the associated strategic advantages therein, and the growing interpretation of sustainability beyond “going green” marketing slogans, will be the first steps in creating a useful framework to better industry through sustainable practices.

The next step in understanding the current activities and mindset of industry was to create an open-ended question. CAS question number six asks respondents to share examples of sustainability from the companies where they work. Responses varied greatly with comments such as “becoming green certified”, “not using paper when possible”, and “having a plugin-hybrid company car” but the large majority of responses were regarding recycling programs and energy savings. In fact, of the sixteen responses to question number six, eleven included some form of recycling and eight included energy saving initiatives. What were not found in the responses to this question were strategies to become more resilient. As discussed in section

2.2 Defining Sustainability, resiliency is the ultimate end-goal of becoming more sustainable. Even beyond the need for basic sustainable progress, such as recycling and energy efficiency, which are all good steps forward, is the need to become resilient at the system level. The CAS was created to interrogate a select sample of business members with the end-goal of creating a framework to help industry achieve system resiliency. The answers to the CAS questions thus far have pointed toward a need for a framework exactly as expected. The last few questions of the CAS will help determine even more so what specific areas the framework should address.

The next question in the CAS states, “In what ways could the company you work for be more sustainable?”. The question was posed to participants to gain an understanding of future sustainability actions that might be possible at the companies where they work. Seventeen of the twenty five respondents chose to answer this question, and five of the seventeen reported a negative outlook toward increased sustainability. The sum of eight respondents not answering the question and five negative answers represents over 50% of the respondents. It is not prodigal to hypothesize that the majority of respondents who declined to answer this question did so because they were either unsure that their company could become more sustainable or did not know actions their companies could take to become more sustainable. Therefore, extrapolating the results from the sample group and applying them to the population being studied, it is evident that industry could benefit greatly from a framework that allows industry members to identify key areas in their businesses that could be made more sustainable and provides specific and simple solutions.

In determining the best way to group the seventeen answers to question seven, four groups were created. Answers were grouped into one of four categories and are divided into the following percentages relative to total answers:

Grouping	Response
Do Nothing	24%
Keep Reducing	59%
Focus on Social Aspects	6%
Change Current Methods	18%

Table 11: CAS Question #7 Summary

Please note that the percentage sum in Table 11 is over one hundred percent due to one respondent giving two answers (a need to keep reducing and focus on social aspects).

The majority of respondents felt that their respective companies should continue to reduce waste and/or material usage which was the typical action already being taken by respondent's companies. A small portion of the respondents saw a need to change current methods to better instill sustainability into the company. The changing of current methods, although the most difficult path, is the action that will result in the largest system shift toward overall sustainability.

Looking at the Focus on Social Aspects section of the Deloitte survey¹, the CAS results reflect the same results found in the previously referenced sustainability survey by Deloitte which established that the social aspect of the Triple Bottom Line was neglected. In further investigating how respondents viewed The Triple Bottom Line, question eight was created.

Question eight in the CAS asked respondents to rank the order of importance for each of the three parts of The Triple Bottom Line (TBL):

Factor	Average
Planet	2.3
Profit	1.95
People	1.75

Table 12: CAS Triple Bottom Line Averages

Although seemingly simple, ranking the three parts of the TBL proved difficult for respondents. Because the averages for each factor are found to be within ± 0.4 of each other this indicates contradictions in rankings among respondents leading to similar averages. The similarity in averages is most likely due to respondents finding each part of the TBL to be of equal importance, as it was designed, and thus struggling to rank the factors.

Looking at the calculated averages in Table 12 above, we see that although the averages are close, participants ranked the three parts of the TBL in order of planet, profit, and then people. This ranking was expected due to the large amount of focus toward helping the planet through sustainable measures while keeping profits high. Previous sustainability surveys with questions regarding the TBL¹, and the previous question in this survey, found that the social factor of the TBL fell to the bottom of the ranking. It is important for all three factors of the TBL to be kept equal when using this simple tool to evaluate areas of business. The use trends for the TBL will be considered when creating an improved framework for industry.

As discussed in section 2.4 Biomimicry, the goal of sustainable actions is to eventually reach a net zero impact where materials used are replaced with materials provided.

Although seemingly impossible, a quickly increasing population will demand a net zero achievement or else run the risk of depleting all resources⁴⁵. In the Current Activities Survey respondents were asked if they thought the business where they work could

eventually achieve the goal of net zero impact. Of the twenty responses to this question, two indicated belief in possibly achieving a net zero impact (10% positive response). It is unfortunate but with the current state of industry, it is very difficult to imagine conducting business without depleting resources, no matter how minute the depletion may be. It was hoped that more respondents would show a positive outlook on achieving net zero impact but the lack of positive responses signifies a large need for describing how net zero impact is essential to survival and how it can be achieved. It is important for sustainability advocates to continue pushing for new system designs that help move industry standards toward the ultimate goal of net zero. In creating a new and improved framework for increasing industry sustainability, results from this CAS question will be considered and the goal of net zero will be used as a benchmark standard and steps toward achievement will be included.

In a follow-up question, respondents were asked what the first step would be to achieve net zero impact. Of the two responses to the previous question, one answered the follow-up question by stating that the first step would be reviewing of current activities and putting a plan in place. This is correct. In fact, after reviewing current activities, mapping the current waste output and redefining system processes to create a more malleable system output is needed. These beginning steps and more can be learned through the use of the creation of a framework tool.

In summary, the Current Activities Survey was successful in gaining a fresh perspective on how industry views sustainability both on an individual level and at a systems level. Respondents were helpful in identifying key actions that the companies where they work are taking to increase sustainability. The CAS also provided a sample of actions that

respondents felt would even better increase sustainability for the companies where they work. As expected, the social aspect of the TBL was ranked last and the large majority of respondents do not feel that achieving net zero impact is possible.

In closing, the last question in the CAS asked respondents if they believed that the company where they work would be open to trying a new framework that may prove to increase sustainability. There was a 90 percent positive response to trying a new framework. Previous sustainability tools and survey responses were taken into careful consideration when building the framework described in the following section. The RISE framework was created with current industry members in mind with the goal of helping real companies see real results.

3.5 “Reshaping Industry Sustainability Efforts” (RISE) Framework

In order to change the way industry identifies potential sustainability actions, the Reshaping Industry Sustainability Efforts (RISE) framework was created to be a simple yet effective way for any industry to assess their system sustainability levels and take decisive action.

In creating the Reshaping Industry Sustainability Efforts framework, the following methodology was created.

1. Research popular sustainability tools
2. Compare the best tools to each other and summarize their pros and cons
3. Define the scope of RISE
4. Design RISE and create related graphics

The first two steps are covered in the literature review. The scope of RISE is defined as a framework aimed to offer standard features available in other tools such as simplicity, graphical display of progress, and interconnectivity. But RISE is also designed to redefine the benchmark for sustainability toolsets by offering a step-by-step method that goes beyond basic sustainability. It is intended to be internationally understandable and draws on established ontologies in sustainability.

Before designing the RISE framework, a brief reflection on the literature review is needed. Looking at the patterns found in the literature review it is apparent that there are three levels of sustainability effort which create a natural progression of sustainability efforts starting with basic sustainability and then moving into resilient systems and finally crescendoing with a fully biomimic model.

Basic sustainability includes recycling programs such as the recycling of paper waste, plastic and glass bottles, and even electronics. It also includes reducing energy consumption and finding alternative energy sources. These green initiatives are often started with good intent but barely scratch the surface of company potential. More times than not basic sustainability initiatives become a showcase for casting a positive light on the company and are mainly used for publicity. Basic sustainability is a Band-Aid applied through the reduction of waste and energy consumption rather than a true solution found through redesigning the system to be inherently sustainable.

Resiliency is the next level of sustainable effort. Designing a resilient system requires the use of redundancies to increase diversity, efficiency, adaptability, and cohesion. Through multiple feedback loops it is possible to design a system which is sustainable by design.

Creating a resilient system often includes identifying system function and boundaries, establishing requirements, selecting appropriate technologies, developing a system design, evaluating anticipated performance, and devising a practical means for system deployment²¹. Resiliency is the first step in creating a system which is inherently sustainable by design.

Biomimicry is the final level of sustainable effort. Industry systems need to become synergetic with the environment they are built upon and around. By the fostering of multiple variations for innovation, systems can mimic the natural world in production development. The use of emergent design, using waste for growth, and incorporating the entire system including the people are all examples of biomimic system characteristics. Achieving these system characteristics is another issue all together.

A structured tool is needed to allow industry to assess individual levels of sustainability effort and take decisive action toward greater and greater sustainable efforts. The RISE framework will foster an efficient understanding of where a company stands regarding sustainable efforts and what the next step is in advancing that company's level of sustainability.

RISE was designed to capitalize on the emergent field of inside-out learning that is fostered by easily assessable media. Potential users of RISE can earn the best results by eagerly applying themselves to understand the progression of sustainability efforts and their respective resources. The RISE framework was created with a reflection upon the CAS results to mitigate potential resistance to acceptance in industry. It includes features such as laying a strong foundation in sustainability understanding, a strong emphasis on

understanding how resiliency can be a large benefit to industry, and how a biomimic system is the final sustainable goal. RISE provides a step-by-step guide to learning how to increase sustainability efforts toward the next level which, according to CAS, was a point of struggle for industry members. Using systems engineering as a platform for a simple example, if the ecosystem we call earth is the main system, then the RISE framework can be related to system requirements necessary for sustaining the system.

Referencing the RISE framework (Table 13), there are 3 levels, indicated by symbolically increasing green hues. Tasks are written as system requirements, or action items, and are listed in an increasing order related to system sustainability. Further resources are suggested on the basis that they are easy to understand and include actionable

Reshaping Industry Sustainability Efforts (RISE)			
Level	Task	Complete	Further Resources
Basic	Get acquainted with change strategies	yes/no	The Green Workplace by Leigh Stringer, The Sustainability Champion's Guidebook by Bob Willard
Basic	Reduce and recycle waste and energy	yes/no	Greening Your Business by Daniel Sitarz
Basic	Implement the Triple Bottom Line	yes/no	The Sustainability Advantage by Bob Willard, Fundamentals of Sustainable Business by Matthew Tueth
Resilient	Understand systems thinking	yes/no	Thinking in Systems by Donella H. Meadows
Resilient	Assess the system as a whole	yes/no	"Circles of Sustainability: An Integrated Approach"
Resilient	Design redundancies to increase stability	yes/no	"Designing Resilient, Sustainable Systems" by Joseph Fiksel
Resilient	Redesign systems to have feedback loops	yes/no	"Designing Resilient, Sustainable Systems" by Joseph Fiksel
Biomimic	Conduct life cycle assessment from systems perspective	yes/no	"Life Cycle Assessment: Principles and Practice" by Mary Ann Curran
Biomimic	Understand biomimicry	yes/no	Biomimicry by Janine M. Benyus,
Biomimic	Design company waste to be reusable internally	yes/no	Cradle to Cradle by William McDonough & Michael Braungart
Biomimic	Create products which upcycle	yes/no	Cradle to Cradle by William McDonough & Michael Braungart

Table 13: RISE Framework

sustainability strategies. Users should generally complete prior tasks before moving on to the next one but there are some tasks that can be started prior to completing the previous task. One or more resources are listed per task to help inform users of the background and methodology related to the task. A waterfall systems requirements flow diagram is created to give a clearer understanding of the general timing and interrelationship of RISE tasks (Figure 15).

Figure 15: RISE Waterfall

To better convey how RISE was designed as an actionable framework, an accompanying flowchart was created. The flowchart depicts the flow of each item on the RISE Framework. It includes executive approval where necessary and has various feedback loops that help to increase the backing of sustainable actions.

Figure 16: RISE Framework Part 1

Figure 17: RISE Framework Part 2

The RISE framework was created to help assist sustainability advocates strategically move to the next level of sustainability and help reshape the ontologies related to sustainable actions. It is intended to facilitate the understanding of natural sustainable progression and help create a healthier ecology for future generations.

Chapter 4: Case Study

To validate the creation of the RISE Framework, one company was randomly chosen and their CAS data was analyzed via the RISE Framework. All respondent names and their associated company names are kept anonymous. CAS data from questions #4-10 was used. First the data for each question is analyzed independently and then the company will be assessed according to the RISE Framework and accompanying flowchart.

The company that was analyzed answered CAS Question #4 in the following order (Table 14):

Statement	Order
Decreasing of waste	1
Redesigning of current industry techniques	2
Building of resilient systems	3
Act of becoming a positive attribute to the environment	4
Recycling of materials	5
Creating of earth-friendly products	6
Minimizing of negative impact	7

Table 14: Case Study CAS Q4

Using several hues of red, the responses for CAS Question #4 are marked darker hues the further they are from the official ranking (Table 15).

No separation
One separation
Two separations
Three separations
+3 separations

Table 15: Comparison to Official Ranking

The results from CAS Question #4 indicate that the respondent has a basic understanding of the increasing levels of sustainable actions but is inclined to favor more basic sustainable actions over true system changes. The respondent is fairly accurate in valuing

the building of resilient systems but left minimizing negative impact as last in importance.

Looking next at CAS Question #5, the responses were color coded according to the level of agreement/disagreement (Table 16).

Statement	Response
Is flexible to changes	Agree
Reacts quickly to economic changes	Strongly agree
Is sustainable	Agree
Believes it is important to build sustainability into the business	Agree
Sets sustainability as a top priority for the company	Neither agree nor disagree
Would be willing to interact with other businesses to become more sustainable	Agree
Sees social aspects of the business as part of sustainability	Agree
Has independent business units that can function separate from each other	Disagree

Table 16: Case Study CAS Q5

Agreement is visually indicated by increasing hues where red shows disagreement, gray shows neither agreement nor disagreement, and blue shows agreement (Table 17).

Strongly agree
Agree
Neither agree nor disagree
Disagree
Strongly Disagree

Table 17: Level of Agreement

The respondent feels that the company where they work has many of the attributes that lead toward a highly sustainable company. It is interesting to note that the respondent does not feel that the company where they work sets sustainability as a top priority even though they feel that the company has many of the attributes which lead toward increased sustainability. Without setting sustainability as a top priority and integrating it into the business model, it is difficult to gain momentum and see true system changes.

It should also be noted that the company does not have independent business units that can function separate from each other. This is an essential part of become a resilient company.

CAS question #6 asked respondents to indicate some examples of applied sustainability from the company where they work. The respondent being studied for this case study responded with several applications. The first was that the company had earned certification of being better for the planet. Secondly, the company had replaced all old lighting with more efficient lighting. Various certifications were earned indicating that the company was a positive influence on its customer's health and the company gives bonuses to employees that car pool or ride bikes to work. The company also has recycling programs and had reduced the use of paper significantly.

Looking at the RISE Framework, all of these applied sustainability actions fall under the basic sustainability section. The respondent can gain a competitive advantage and prepare to move the company into the next level by understanding the resources indicated in RISE. According to the RISE Framework Flowchart, the next step for this company would be to go back to the beginning and assess various change strategies while getting executives on board regarding the use of the TBL as a main benchmark. It would be wise for this company, as they are taking the previously mentioned actions, to begin evaluation how their systems can be redesigned and how setting sustainability as a top priority will increase profit margins while preparing them for future restrictions in legislation.

Reshaping Industry Sustainability Efforts (RISE)			
Level	Task	Complete	Further Resources
Basic	Get acquainted with change strategies	yes/no	<u>The Green Workplace</u> by Leigh Stringer, <u>The Sustainability Champion's Guidebook</u> by Bob Willard
Basic	Reduce and recycle waste and energy	yes/no	<u>Greening Your Business</u> by Daniel Sitarz
Basic	Implement the Triple Bottom Line	yes/no	<u>The Sustainability Advantage</u> by Bob Willard, <u>Fundamentals of Sustainable Business</u> by Matthew Tueth
Resilient	Understand systems thinking	yes/no	<u>Thinking in Systems</u> by Donella H. Meadows
Resilient	Assess the system as a whole	yes/no	"Circles of Sustainability: An Integrated Approach"
Resilient	Design redundancies to increase stability	yes/no	"Designing Resilient, Sustainable Systems" by Joseph Fiksel
Resilient	Redesign systems to have feedback loops	yes/no	"Designing Resilient, Sustainable Systems" by Joseph Fiksel
Biomimic	Conduct life cycle assessment from systems perspective	yes/no	"Life Cycle Assessment: Principles and Practice" by Mary Ann Curran
Biomimic	Understand biomimicry	yes/no	<u>Biomimicry</u> by Janine M. Benyus, <u>Biomimicry.net</u>
Biomimic	Design company waste to be reusable internally	yes/no	<u>Cradle to Cradle</u> by William McDonough & Michael Braungart
Biomimic	Create products which upcycle	yes/no	<u>Cradle to Cradle</u> by William McDonough & Michael Braungart

Figure 18: RISE Case Study Framework Example

Looking at the figure above, it can be seen that the company chosen for the case study has started to become acquainted with change strategies but still needs to reduce consumption patterns and begin to reassess how they can implement the Triple Bottom Line. If the TBL was truly understood by the business then there would not be a lack of resources as mentioned in the answer to CAS question seven.

With a revaluation of reduction strategies and the TBL, this company will be ready to move toward increasing resilience in their systems. Further resources include Greening Your Business, The Sustainability Advantage, and Fundamentals of Sustainable Business.

Chapter 5: Conclusions and Future Directions

The future of humanity lies in the decisions taken today and tomorrow. Decisions taken yesterday cannot be changed. Fully adopting sustainability is the key to future success for both industry and the consumer.

The biggest question of this century is how to change current industry systems to fully sustainable models. There has been a lot of commotion surrounding applied sustainability and evolving current businesses into green businesses yet there is a huge lack in the understanding of not only what it means to be truly sustainable but how to reach this seemingly impossible goal.

In researching the vast majority of the applied sustainability techniques in literature, a common theme can be drawn and defined as three main segments of the natural sustainability progression. The first segment is basic sustainability. This includes the typical positive publicity actions of increased recycling, energy efficiency, and earth-friendly branding. Although not poor in nature, it is the second segment that produces much increased results. Progressing beyond basic applications, resiliency becomes the main focal point. The second segment in the sustainability progression encompasses system changes through feedback loops and increased stability. The last segment of sustainability progression is the biomimic segment which truly involves a transformation from resilient stability to positively affecting the surrounding environment and ecosystem.

Of the few sources available on how to start the transformation from being apart from nature to a part of nature even fewer offer a transformative action plan for established industries. It is the challenge of identifying key change strategies and then taking action toward increased sustainability that companies struggle with. Fortunately, the new framework laid out in this thesis leaves no room for inaction and indeed makes it easier for industries to RISE to the occasion.

Bibliography

- [1] "New Deloitte Report Highlights a Clear Recognition of the Importance of Sustainability to the Future of Businesses Among Cross-Sector Leaders." *Csrwire.com*. Corporate Social Responsibility Wire, 27 July 2010. Web. 25 Feb. 2013.
- [2] Park, Chris and Kathryn Pavlovsky. "Sustainability in Business Today: A Cross-Industry View." Deloitte. 2010. Web. 9 Sept. 2012
- [3] "Biomimicry Applied." *Ecos* 129 (2006): 28-29. Academic Search Elite. Web. 30 Sept. 2012.
- [4] Albertson, Timothy L. "The Integration of Biomimicry into a Built Environment Design Process Model: An Alternative Approach to Hydro-Infrastructure." Thesis. University of Nevada, 2010. *ProQuest*. Web. 3 Oct. 2012
- [5] Reed, Philip A. "A Paradigm Shift: Biomimicry (Cover Story)," *Technology Teacher* 63.4 (2003):23-27. Academic Search elite. Web. 30 Sept. 2012.
- [6] [7] Nakram, Sunil and Craig Tovey. "From Honeybees to Internet Servers" IOP Publishing. *Bioinspired & Biomimicry*. 2(2007): 5182-5197. Print.
- [8] Vanderbilt, Tom. "Better Living Through Imitation." *Smithsonian* 43.5 (2012): 50-53. Academic Search Elite. Web. 30 Sept. 2012.
- [9] Benyus, Janine M. *Biomimicry: Innovation Inspired by Nature*. HarperCollins Publishers Inc. New York, NY. 1997.
- [10] Triple Bottom Line. *The Economist*. November 17th 2009. Web. 3 Nov. 2012.
- [11] *12 Sustainable Ideas from Nature*. Janine Benyus. TED Monterey, CA. May 27, 2009.
- [12] Whal. "Bionics vs. Biomimicry: From Control of Nature to Sustainable Participation in Nature." Centre for the Study of Natural Design, University of Dundee, UK. *WIT Transactions on Ecology and the Environment*, Vol 87, 2006 WIT Press. Web. 14 Oct. 2012. Page 1.
- [13] *e2: Green For All*. Dir. Tad Fettig Perf. Brad Pitt. Kontentreal LLC in association with PBS, 2006. Web. 14 Oct. 2012
- [14] Tueth, Matthew. *Fundamentals of Sustainable Business*. World Scientific, New Jersey 2010.
- [15] Willard, Bob. *The Sustainability Champion's Guidebook: How to Transform Your Company*. New Society Publishers, Canada, 2009.
- [16] Gladwell, Malcom. "Blowing Up". *The New Yorker*, April 22 & 29 2002. Pg. 170
- [17] Kirchain, Randolph E. MIT Materials Systems Lab. Web 30 Oct. 2012. <http://msl.mit.edu/kirchain/kirchain-research-environmental.html>

- [18] T. Herbertsson, Sources of Economic Growth, University of Iceland Press, Reykjavik, Iceland (1999).
- [19] Stringer, Leigh. The Green Work Place. Palgrave Macmillian. New York, NY. 2009.
- [20] Meadows, Donella H. Thinking in Systems. Sustainability Institute. 2008.
- [21] Fiksel, Joseph. "Designing Resilient, Sustainable Systems". Environ. Sci. Technol. 2003, 37, 5330-5339. Web. 11 Nov. 2012.
- [22] *Surviving Progress*. Dir. Mathieu Roy. Perf. Ronald Wright. Big Picture Media Corporation, 2011. DVD. *Netflix*. Netflix Inc. Web. 13 Jan. 2013
- [23] Mieroop, Mark Van De. *The Ancient Mesopotamian City*. Oxford: Clarendon, 1997. Print.
- [24] McDonough, William, and Michael Braungart. *Cradle to Cradle: Remaking the Way We Make Things*. New York: North Point, 2002. Print.
- [25] Lucas, Robert E., Jr. (2002). *Lectures on Economic Growth*. Cambridge: Harvard University Press.
- [26] Woodward, D. (1981) *Wage rates and living standards in pre-industrial England Past & Present* 91(1):28-46
- [27] Rosen, William (2012). The Most Powerful Idea in the World: A Story of Steam, Industry and Invention. University Of Chicago Press. pp. 149.
- [28] Creech, Heather. Sustainable Development Timeline. International Institute of Sustainable Development. 2012. Web. Feb 4 2013. Page 1, 4
- [29] Malthus. *An Essay On The Principle Of Population*. Norton Critical Editions. 1803.
- [30] The Sydney Morning Herald."Risks of Economic, Ecological Collapse." 10 Jan. 2013. Web. 10 Feb. 2013.
- [31] Nasser, Haya El. "World Population Hits 7 Billion." *USATODAY.COM*. USA TODAY, 31 Oct. 2011. Web. 18 Feb. 2013.
- [32] Yadong , Y. (2013). Eco-efficiency trends in china, 1978-2010:decoupling environmental pressure from economic growth. *Ecological Indicators*, 24, 177-184.
- [33] Laughland, Pamela, and Tima Bansal. "THE TOP TEN REASONS WHY BUSINESSES AREN'T MORE SUSTAINABLE." *Ivey Business Journal*. Ivey Business Journal, Feb. 2011. Web. 21 Feb. 2013.
- [34] Wright, Ronald. *A Short History of Progress*. New York: Carroll & Graf, 2005. Print.
- [35] "Millennium Development Goals Indicators." *Http://mdgs.un.org*. United Nations, 15 Jan. 2008. Web. 02 Mar. 2013.

- [36] James Hull, "The Second Industrial Revolution: The History of a Concept", *Storia Della Storiografia*, 1999. Issue 36.
- [37] "Rio Declaration on Environment and Development." *Rio Declaration*. United Nations Environmental Programme, n.d. Web. 11 Mar. 2013.
- [38] "FULL TEXT OF THE CONVENTION, ARTICLE 2." *United Nations Framework Convention on Climate Change*. United Nations, n.d. Web. 11 Mar. 2013.
- [39] "Health of the Planet Survey." *Datalib.chass.utoronto.ca*. Princeton, New Jersey: George H. Gallup International Institute, 29 Jan. 2010. Web. 12 Mar. 2013.
<<http://datalib.chass.utoronto.ca/inventory/1000/1078.htm>>.
- [40] "ISO 14000 - Environmental Management." *ISO.org*. International Organization for Standardization., n.d. Web. 13 Mar. 2013.
- [41] Boiral, Olivier. "Corporate Greening Through ISO 14001: A Rational Myth?" *Organization Science* 18.1 (2007): 127-46. Print.
- [42] Meyer, J. W., B. Rowan. 1997. Institutional organizations: Formal structure as myth and ceremony. *Amer. J. Sociol.* 83(2) 340-363.
- [43] Reger, R. K, L. T. Gustafson, S. M. Demarie, J. V. Mullane. 1994. Reframing the organization: Why implementing total quality is easier said than done. *Acad. Management Rev.* 19(3) 565-584.
- [44] Lacy, Peter, Tim Cooper, Rob Hayward, and Lisa Neuberger. "A New Era of Sustainability." *UNglobalcompact.org*. Accenture and The United Nations, 2010. Web. 15 Mar. 2013.
- [45] Diamond, Jared M. *Collapse: How Societies Choose to Fail or Succeed*. New York: Viking, 2005. Print.
- [46] Cerruti, James L. "Keys To Sustainability Leadership." *SustainabilityLeadershipReport.com*. Brand Logic, 2012. Web. 12 Apr. 2013.
- [47] "Green Transition Inflection Point: Green Transition Scoreboard 2013". St. Augustine: Ethical Markets Media LLC, 2013. Web. 4 Apr. 2013.
- [48] "Circles of Sustainability: An Integrated Approach." *Global Compact Cities Programme*. The Global Compact, n.d. Web. 19 Apr. 2013.
- [49] Emerson, J.W., A. Hsu, M.A. Levy, A. de Sherbinin, V. Mara, D.C. Esty, and M. Jaiteh. 2012. *2012 Environmental Performance Index and Pilot Trend Environmental Performance Index*. New Haven: Yale Center for Environmental Law and Policy.
- [50] "Technical Protocol: Applying the Report Content Principles." *Globalreporting.org*. Global Reporting Initiative, 2011. Web. 30 Apr. 2013.

- [51] Verdoorn, Allison. "Conduct a Mini Life Cycle Assessment." *ApartmentTherapy.com*. Apartment Therapy, 16 Aug. 2010. Web. 02 May 2013.
- [52] Curran, Mary Ann. "Life Cycle Assessment: Principles and Practice". Scientific Applications International Corporation, Reston VA. 2006. Print.
- [53] Ward, Barbara, and René J. Dubos. *Only One Earth*. Tokyo: Nan'un-do, 1973. Print.
- [54] Meadows, Donella H. *The Limits to Growth; a Report for the Club of Rome's Project on the Predicament of Mankind*. New York: Universe, 1972. Print.
- [55] Meadows, Donella H., Jørgen Randers, and Dennis L. Meadows. *The Limits to Growth: The 30-year Update*. White River Junction, Vt: Chelsea Green Pub., 2004. Print.
- [56] "World Conservation Strategy: Living Resource Conservation for Sustainable Development". Gland, Switzerland: IUCN, 1980. Print.
- [57] "Global Strategy for Health for All by the Year 2000. Geneva: World Health Organization", 1981. Print.
- [58] "Global 2000 Report: Hearing before the Subcommittee on Census and Population of the Committee on Post Office and Civil Service", House of Representatives, Ninety-seventh Congress, First Session, May 12, 1981. Washington: U.S. G.P.O., 1981. Print.
- [59] "World Health Assembly." *WHO*. World Health Organization, n.d. Web. 16 May 2013.
- [60] World Commission on Environment and Development. "Our Common Future". Oxford: Oxford UP, 1987. Print.
- [61] Schmidheiny, Stephan. *Changing Course: A Global Business Perspective on Development and the Environment*. Cambridge, MA: MIT, 1992. Print.
- [62] "Agenda 21, Rio Declaration, Forest Principles". [New York]: United Nations, 1992. Print.
- [63] Dunlap, Riley E., and Alec M. Gallup. *Health of the Planet: Results of a 1992 International Environmental Opinion Survey of Citizens in 24 Nations*. Princeton, NJ: George H. Gallup International Institute, 1993. Print.
- [64] Fowler, Floyd J. *Improving Survey Questions: Design and Evaluation*. Thousand Oaks: Sage Publications, 1995. Print.
- [65] Dunbar, Brian. "NASA, NOAA Data Indicate Ozone Layer Is Recovering." *NASA*. NASA, 30 Aug 2006. Web. 04 May 2013.
- [66] Stern, N. H. *The Economics of Climate Change: The Stern Review*. Cambridge, UK: Cambridge UP, 2007. Print

Appendix A

CAS Survey

Intro

This survey was created in order to gather current business perspective on sustainability for the purpose of gauging a benchmark for developing and tracking changes in sustainable practices. Your participation in this survey will help foster an understanding of the role resilient designs can play in creating a truly sustainable global industrial ecosystem. Information is being collected for use in a Cal Poly industrial engineering thesis, and all responses are confidential. Please answer as openly and frankly as possible.

This survey is a total of 10 questions and will take approximately 8 minutes to complete.

A Couple Quick Definitions

Sustainability (business) – an enterprise that has minimal negative impact on the global and local environment, community, society, and economy

Resilient – the positive ability to respond to and quickly recover from non-productive events

Questions

1. What is name of the company where you work?
2. What type of work do you do for this company?
3. What main raw material does this company use in its processes (plastics, metals, polymers, textiles, information, etc)?
4. Please rank the importance of the following statements, from #1-#7, when defining sustainability (i.e. Sustainability is the...)

- ___ Building of resilient systems
- ___ Act of becoming a positive attribute to the environment
- ___ Recycling of materials
- ___ Creating of earth-friendly products
- ___ Redesigning of current industry techniques
- ___ Minimizing of negative impact
- ___ Decreasing of waste

5. Please indicate how the company you work for views each of the following statements.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Is flexible to changes	☐	☐	☐	☐	☐
Reacts quickly to economic changes	☐	☐	☐	☐	☐
Is sustainable	☐	☐	☐	☐	☐
Believes it is important to build sustainability into the business	☐	☐	☐	☐	☐
Sets sustainability as a top priority for the company	☐	☐	☐	☐	☐
Would be willing to interact with other businesses to become more sustainable	☐	☐	☐	☐	☐
Sees social aspects of the business as part of sustainability (e.g. societal impacts, employee wellbeing, etc.)	☐	☐	☐	☐	☐

Has independent business units that can function separate from each other	☐	☐	☐	☐	☐
---	--------------------------	--------------------------	--------------------------	--------------------------	--------------------------

6. Please share some examples of applied sustainability at the company where you work.
7. In what ways could the company you work for be more sustainable?
8. Please rank the following company sectors from most to least important when applying sustainable design (1 = least important, 3=most important)
 - ___ People
 - ___ Planet
 - ___ Profit
9. Do you think it's possible for the company you work at to have a net zero impact (e.g. no negative environmental impact)?
 - a. If so, what would be the first step in attaining a net zero impact?
10. Do you believe the company you work for would be willing to try a new methodology/framework that may prove to help them build stronger sustainability/resilience in their business?
 - a. What would be the one key feature you would want to see available in this framework (e.g. "This framework should be able to help us do _____)? Why?

Thank you for participating in this survey. Your responses are greatly appreciated. If you would like a copy of the thesis in which responses are used, please indicate this below, and a copy will be shared with you when it is published.