Investigation of Greenhouse Gas Reduction Strategies by Industries – An Enterprise Systems Architecting Approach

By

Kumaresh Babu Tanthullu Athmaram

M.Tech., Automotive Engine Technology, Indian Institute of Technology, Chennai, India, 2002
B.E., Production Engineering, National Institute of Technology, Tiruchirappalli, India, 1998

Submitted to the System Design and Management Program in Partial Fulfillment of the Requirements for the Degree of

Master of Science in Engineering and Management

at the

Massachusetts Institute of Technology

January 2012
[February 2012]

Signature of Author: _____
System Design and Management Program
January 13, 2012

Certified By: _____
Donna H. Rhodes, Thesis Supervisor
Senior Lecturer, Engineering Systems Division

Accepted By: _____
Patrick Hale, Director
System Design and Management Program

This page has been intentionally left blank.

Investigation of Greenhouse Gas Reduction Strategies by Industries – An Enterprise Systems Architecting Approach

By

Kumaresh Babu Tanthullu Athmaram

Submitted to the System Design and Management Program on January 13, 2012 in Partial Fulfillment of the Requirements for the Degree of Master of Science in Engineering and Management

Abstract

This thesis explores an enterprise systems architecting approach to investigate the greenhouse gas reduction strategies followed by industries, especially for automotive industry and Information Technology industry. The strategic dimensions of greenhouse gas reduction aspects-drivers, actions and challenges-faced by industries are identified and a survey was circulated among the senior and mid-level managers of both industries. The survey results are compiled and analyzed to understand the leading drivers, actions and challenges in addition to the ranking of the eight views of enterprise architecting. The results are then used to identify gaps between the current status and the envisioned future state of the companies, based on the survey results, internal assessments and prevailing state of the art greenhouse gas reduction strategies. Several candidate architectures are developed based on the identified gaps for both industries. An alignment matrix for all the eight views with the candidate architectures is also developed. Generic frameworks to evaluate candidate architectures using 'ilities' and weighting factors are discussed. Greenhouse gas profiles of both the industries are compared, and future research scope to extend this thesis is presented.

Thesis Supervisor: Donna H. Rhodes

Title: Senior Lecturer, Engineering Systems Division

This page has been intentionally left blank.

Acknowledgement

It is a pleasure to thank those who made this thesis possible and influenced me to have a wonderful experience at MIT. First, I would like to thank my supervisor Donna Rhodes, for her continuous encouragement and support throughout my stay at MIT. I thank her for expressing an appreciation for my research interest to fuse sustainability and enterprise architecting and for granting freedom to work on my thesis.

I would like to thank Pat Hale for helping in customizing my courses to support this thesis. I would also like to thank all the survey responders, who shared their time and insights on this complex topic. I also offer a heartfelt thanks to all my friends in SDM who helped not only to prepare the survey questions, but also to feed me with lot of energy and enthusiasm throughout my stay. Thanks to them for being patient with me.

I owe my deepest gratitude to my selfless family members- parents, wife, kids, brother and in-laws, who constantly supported me emotionally and financially to follow my dreams.

This page has been intentionally left blank.

Table of Contents

This page has been intentionally left blank.

1.0 Introduction

1.1 Motivation

In spring 2011, as a part of Strategic Sourcing (MIT ESD.930) class, I worked with a major food company in the USA to identify and reduce the Greenhouse gas (GHG) emissions for the company's external supply chain operations. The project scope was to identify carbon intensive stages in the upstream processes of five agricultural inputs including beef, poultry, oil, tomato and flour. My 4-member team conducted a lifecycle study using Lifecycle Analysis Software and Economic Input Output Model [1] to analyze the GHG emitted in the lifecycle processes. Our results identified several carbon intensive operations in the lifecycle of the products such as fertilizer use, tractor use efficiency and specific operational steps in the production process of the agricultural inputs. Based on our analysis we recommended certain operational decisions and strategies to reduce GHG. Our insights helped the company to mobilize their resources to execute the actionable solutions recommended by my team.

This project inspired my interest to explore more about the inclusion of sustainability issues in the business agenda of the companies. Companies in many industries are facing new environmental challenges, including heightened uncertainty about environmental regulation, and intensifying demands for accountability and transparency regarding environmental management and performance. At the same time, climate change and water resources are of growing strategic importance. In this context, companies need to understand the factors that drive business value when dealing with the environment, both to recognize business opportunities and to manage business risks. Companies need to better understand how to engage these issues with stakeholders, including investors, regulators, and non-governmental organizations, as well as customers and suppliers

In spring 2011, I took Enterprise Architecting class (MIT ESD.38J) and learned about MIT Lean Advancement Initiative (LAI)'s eight view enterprise systems architecting framework. I realized the immense benefits of using such robust framework to identify and prioritize the actions that are required to achieve short term and long term goals of the company. LAI's Enterprise Architecting framework can be applied to specific departments, business units, organization, enterprise or the industry sector. The intrinsic nature of the two subjects, that is, extensive stakeholder engagement in prioritizing and addressing sustainability issues and the methodology offered by LAI's eight view framework to address such issues inspired me to explore the fusion of these two subjects.

1.2 Scope

The key question this thesis tries to answer is how companies can effectively use MIT LAI's eight view enterprise architecting principles to integrate business entities in addressing their sustainability issues. This thesis is focused on the following questions:

- What are the drivers for the industries to focus on GHG reduction?
- What are the actions that industries can perform to reduce GHG? What are the incentives?
- What challenges do they face while the companies work towards the sustainability goals? How do they weigh internal and external factors to manage the challenges?
- How can the organization and stakeholders be better aligned to reach the objective? What frameworks help them? How do companies prioritize their actions?

Two industry sectors-automotive industry and information technology industry-are chosen to explore the applicability of the enterprise systems architecting framework, to demonstrate the versatility and universality of the systems architecting tools. A note on further research scope is also discussed in this report.

1.3 Research Methodology

This thesis will explore the application of MIT LAI's eight view framework to industries in general to identify the gaps between the current status and envisioned future, especially in terms of reducing greenhouse gas (GHG) emissions. Two types of surveys were used to gather information. A literature survey has been conducted to understand the collective dimensions- Driver, Actions and Challenges- that influence industries to reduce carbon footprint. A stakeholder survey has been conducted for this study to understand the drivers, actions and challenges from the mid and senior level managers in the automobile industry and Information Technology industry. The survey data is aggregated and a gap analysis has been done with respect to the industry standard and expectations. Based on the identified gaps, several candidate architectures were developed. A generic framework to evaluate candidate architectures is also presented.

This thesis proceeds as follows. Chapter 2 introduces important sustainability frameworks and chapter 3 provides an overview of enterprise systems architecting. Chapter 4 discusses some strategic dimensions of carbon footprint reduction – Drivers, Actions and Challenges, which are included in the survey. Chapter 5 and 7 summarize the survey response from the automotive industry and information technology industry respectively. Chapters 6 and 8 explain the gap analysis and the evolution of candidate architectures. A generic framework of evaluating candidate architectures is also presented. Chapter 9 introduces the importance of transformation plan and heuristics involved in enterprise systems architecting. Chapter 10 compares several common aspects of the greenhouse gas reduction mechanisms for the two industries selected in this thesis. Chapter 11 discusses in brief the future research scope to encompass epoch-era considerations and balanced scorecard concepts in enterprise architecting for sustainability issues.

2.0 Sustainability Frameworks

Sustainability has various definitions and meanings. It can range from protecting an endangered species to mitigating climate change effects. Sustainability can be measured in different dimensions and there are numerous trade-offs to be considered by companies in order to be environmental friendly. This section explains four leading sustainability frameworks, to understand sustainability, beyond the boundaries of GHG reduction. The four leading frameworks are: the Triple Bottom Line, The Natural Step, the Ecological Footprint and Graedel and Klee's method to calculate sustainable emissions and resource usage [2].

2.1 The Triple Bottom Line

This framework believes that organizations pursuing sustainability need to make decisions not only based on economic performance but also on environmental protection and social justice [3]. The three elements of the triple bottom line are economic, environmental and social bottom line. Economic bottom line refers to the economic returns and goals of the company. Social bottom line refers to the social equity with respect to environmental protection and environmental bottom line refers to the eco-efficiency and the environmental protection [3]. Since all the objectives are important to the society, advocates of Triple Bottom Line advocate that the companies should consider them in daily decisions. However critics have argued that "the triple bottom line concept lacks a meaningful foundation. Companies should have other bottom lines beyond profit but they don't stop at three – they should have an ethical bottom line, for example" [4].

2.2 The Natural Step

The Natural Step defines a sustainable society as one where four conditions are met: "nature is not subject to systematically increasing (a) concentrations of substances extracted from earth's crust, (b)

concentrations of substances produced by society, or (c) degradation by physical means; and, in that society, (d) human needs are met worldwide [5]. Some critics have argued that "By this definition, some of the current trends are unsustainable, including the combustion of fossil fuels, which increases concentrations of atmospheric carbon dioxide; emissions of persistent bio accumulative chemicals; systematic loss of rainforest and wetlands; and a substantial under nourished population" [2]. The Natural Step framework is "unique in that it does not constrain individuals to work only with existing technologies, political systems and laws" [6]. Several companies, in general, are exploring how to apply The Natural Step framework to their business strategy and operations [7].

2.3 The Ecological Footprint

Marshall and Toffel claimed that "The Ecological Footprint compares the environmental impact of specific actions to the limitations of the earth's natural resources and ecosystem functionality" [2]. The Ecological Footprint calculates a ratio of "how many earths" would be required to provide enough biologically productive land area to maintain the flows of resources and wastes, if everyone lived like a specific person or group of people [8]. The Ecological Footprint highlights global inequity in resource consumption.

2.4 Graedel and Klee's Sustainable Emissions and Resource Usage

Graedel and Klee [9] proposed a four step process for determining a sustainable rate of resource use : (a) calculate the available supply of virgin materials (mass) ; (b) allocate consumption of this supply over a specific time scale and among the global population (mass per person per year); (c) account for recycling and for existing stockpiles including landfills and then update the allocated consumption rate and (d) consider this rate to be the maximum sustainable consumption rate and compare it to the current usage rate. Marshall and Toffel [2] claimed that the methods used by Graedel and Klee to

compare the sustainable emission rates highlight that "assessing whether a consumption or emission rate is sustainable requires specifying an explicit time scale".

2.5 Sustainability Hierarchy

Marshall and Toffel [2] explain that "while the Brundtland[1] definition identifies meeting future human needs as the goal of sustainability, the four sustainability frameworks highlighted above are ambiguous with regard to *what* is being sustained. The widespread use of the label "unsustainable" has referred to several distinct but related concepts". Marshall and Toffel developed a Sustainability Hierarchy as shown in Figure 1.

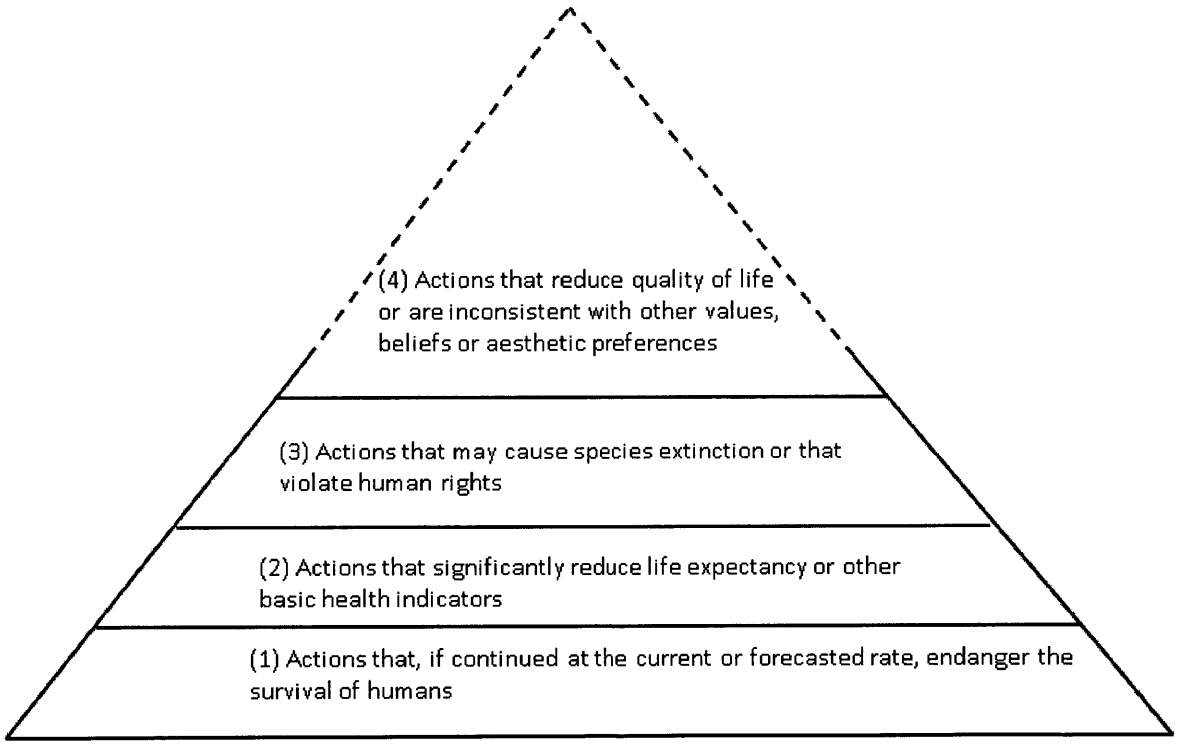

Figure 1 Sustainability Hierarchy, Adapted from Marshall and Toffel, 2005

[1] According to Brundtland Commission definition, Sustainability refers to meeting the needs of the current generation without compromising the ability of future generations to meet their needs.

Authors Marshall and Toffel [2] claimed that "while level 4 issues are important, they should not be considered within the rubric of sustainability".

2.5.1 Business Implications

Understanding the business implications of the sustainability hierarchy shown in Figure 1 is critical to comprehend the type of sustainability issues that companies want to solve. Categorizing sustainability or carbon footprint issues based on the environmental impact, requires deeper understanding of the lifecycle of the products. Identifying carbon intensive operations throughout the lifecycle of the products is crucial to categorize them in to appropriate levels to emphasize the seriousness of the issues. The carbon footprint of the organization extends beyond its organizational boundaries and the net impact of systems level emission considering its upstream and downstream processes can be reduced by various methods. The sustainability of the organizations products or services depend on various factors such as production methods, consumption pattern, and recycling efforts involved in the ultimate disposal of the products. Considering the example of automobile use with respect to the hierarchy levels, Marshall and Toffel [2] explained that, "many people would consider the fossil fuel internal combustion engine to be unsustainable at several levels of the hierarchy. It is unsustainable at level 1 because, at current and forecasted usage, consumption of fossil fuels exceeds regeneration rates and pollutant emissions exceed assimilative capacities and are leading to the decline of ecosystem function (e.g., by contributing to global climate change). However, internal combustion engines are not inherently sustainable or unsustainable: if the use of such engines consumed resources at or below regenerative rates and produced wastes within assimilation rates, then they would not impair ecosystem function and their use would be sustainable at level. Because motor vehicles are a significant contributor to the hazardous air pollutants that are ubiquitous to urban areas, they are not sustainable at level 2. If their emissions were adequately controlled, however they could be

sustainable at this level. Finally level 4 proponents might find vehicles' noise pollution and haze/ visibility impacts to be unsustainable on an aesthetic basis".

The example described above, opens up some interesting aspects to be considered by the companies as discussed below:

- Prioritization of sustainability issues as mentioned by different levels of the sustainability hierarchy will be a crucial understanding for the industries
- Importance of systems thinking and holistic view towards the problem at hand, and avoiding a piecemeal approach for solving sustainability issues
- Knowledge of the internalities and externalities in handling sustainability issues
- Stakeholder segregation, for example are we satisfying the stakeholders in level 4 or in level 2

LAI's enterprise systems architecting framework helps to understand the above mentioned points by applying specific frameworks. However, selection and use of any sustainability frameworks by the companies depends on the vision, leadership, current and future needs of the companies. As mentioned above, every sustainability framework has its own merits and demerits. But the commitment of the companies should be genuine towards environmental sustainability and should avoid Greenwashing[2].

2.6 Greenhouse Gases

As discussed in section 2.5.1, related to the automobile example, carbon dioxide emissions from fossil fuels is considered under level 1 of the sustainability hierarchy and therefore is a serious concern today. GHGs of greatest concern included carbon dioxide, methane, nitrous oxide and two types of industrial

[2] Greenwashing is a form of spin in which green public relations or green marketing is deceptively used to promote the perception that a company's policies or products are environmentally friendly.(Source: http://en.wikipedia.org/wiki/Greenwashing#cite_note-Not-0)

chemicals, hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) [10]. Climate change risks caused by increase in the concentration of Greenhouse Gases may prove to be most important business issue of this century. By 2007, the Intergovernmental Panel on Climate Change (IPCC), the world's leading international organization that synthesized climate science and was established by the United Nations and the World Meteorological Organization, had concluded that "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and that most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic [human-caused] GHG concentrations" [11].

In response, many governments and companies had begun to take actions to reduce greenhouse gas emissions. All industrialized countries except the United States had ratified the Kyoto Protocol, a United Nations treaty that required emissions reductions of 5% below 1990 levels by 2012 [12]. Hence companies can no longer avoid their contribution to abate or eliminate their emissions footprint. Industries should extend their operational and strategic control beyond their organizations and should have a systems view of their enterprise in addressing sustainability issues. Industries should assume responsibility to reduce GHG emissions in both upstream and downstream processes, not limiting to its own internal functions. Companies have started conducting lifecycle analysis to understand the carbon intensive process in its operations including upstream and downstream processes.

An organization's carbon footprint can be split as internal and external footprints. Internal footprint includes the total GHG emissions that directly result from a company's onsite operations (e.g. fossil fuel combustion in boilers and fleet vehicles, chemical reactions in some manufacturing processes), and often also includes GHG emissions associated with purchased electricity. An organization's external carbon footprint may also include other indirect sources of GHG emission, such as those associated with

the production and transportation of raw materials as well as the distribution and disposition of its products [13].

3.0 Enterprise Systems Architecting

There are various definitions available for defining an enterprise. The Black's law dictionary defined an enterprise as "One or more organizations that have related activities, unified operation or common control, and a common business purpose" [14]. Nightingale and Rhodes explained that "Enterprises have long been studied by management scientists and social scientists; however, this has largely been through taking one single view of the enterprise such as studying the organizational structure or the information architecture. *Enterprise Systems Architecting* is a new strategic approach which takes a systems perspective, viewing the entire enterprise as a holistic system encompassing multiple views such as organization view, process view, knowledge view, and enabling information technology view in an integrated framework" [15]. There are many aspects of an enterprise system that must be considered, including: political, cultural, legal, economic, environmental, technological, sociological, psychological, geographical, and temporal.

There are multiple stakeholders in today's enterprise. Freeman defines a stakeholder as "any group or individual who can affect or is affected by the achievements of the organization's objective" [16]. Figure 2 shows the multiple stakeholders involved with the enterprise. The above definitions are useful in understanding organizations not as a single entity but as a part of the whole system including its upstream and downstream processes. These definitions also help us in possible clustering of some companies or industries who share a common business purpose. Nightingale and Rhodes claimed that the definition of enterprise is contextual and "enterprise context is the environment in which the

enterprise operates including the exogenous influences and uncertainties" [14]. Authors Nightingale and Rhodes also added that "The new enterprises that are evolving are highly complex and the management approaches applied are shifting from the modern to postmodern" [15] [17].

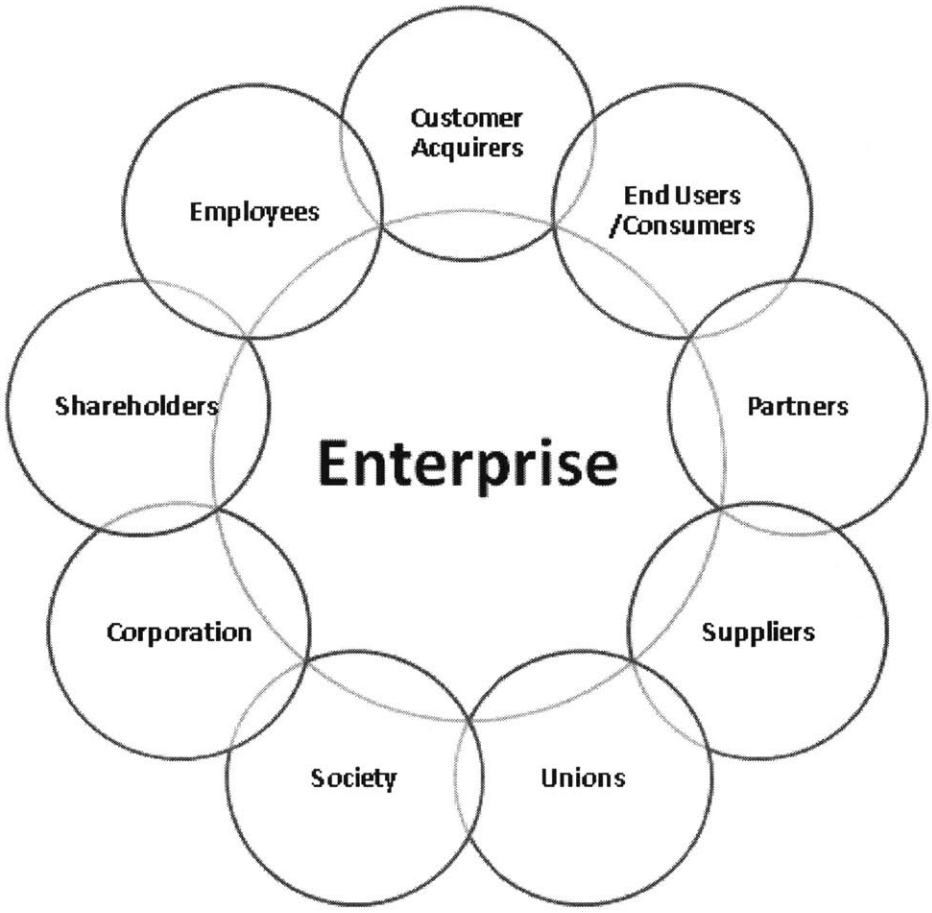

Figure 2 Stakeholders of Enterprise

Enterprise architecture frameworks provide a formal and highly structured way of viewing and defining an enterprise and preparation methods for transformation. Nightingale and Rhodes define Enterprise Architecting as "Applying holistic thinking to design, valuate and select a preferred structure for a future state enterprise to realize its value proposition and desired behaviors" [14]. In this thesis, the important stakeholders considered are shareholders, management, customers and suppliers.

A generic process framework for a highly effective enterprise developed by Nightingale and Mize is shown in Table 1 [18].

Lifecycle Processes • Business Acquisition & Program Management • Requirements Definition • Product/ Process Development • Supply Chain Management • Production • Distribution and Support	Life Cycle Processes define the product life cycle, from initial conception through design, development, production and operational support. These are the value steam activities that contribute directly to the creation of products, systems, or services delivered to the enterprise's customers. These processes reflect the lean view of an overall product lifecycle within which functions serve, as opposed to the more traditional paradigm that allows each function to sub-optimize around its own operations.
Enabling Infrastructure Processes • Finance • Information Technology • Human Resources • Quality Assurance • Facilities and Services • Environment, Health and Safety	Enabling Infrastructure Processes support the execution of Enterprise Leadership and Life Cycle Processes. The enabling processes provide supporting services to other organizational units whom they serve as internal customers. Since they enable rather than directly results in enterprise success, they can be easily overlooked. In a lean enterprise, though they are reoriented to support the 'Life Cycle Processes'
Enterprise Leadership Processes • Strategic Planning • Business Models • Managing Business Growth • Strategic Partnering • Organizational Structure & Integration • Transformation Management	Enterprise Leadership Processes are developed and maintained by leadership to guide the activities of the enterprise. They cut across all of the entities that make up the enterprise. Enterprise leadership provides the direction and resources to break down barriers among and within Life Cycle Processes in order to create increased value to customers and stakeholders. They also provide the leadership to apply the enabling processes to improve responsiveness to the rest of the enterprise. Many of the leadership processes such as business models, strategic partnering and organizational structures and integrations are highly significant in architecting enterprises.

Table 1 LAI Generic Lean Enterprise Process Framework Source: MIT Engineering Systems Symposium, March 2004

3.1 Eight Views Framework

MIT's Lean Advancement Initiative (LAI) and Systems Engineering Advancement Research Initiative (SEAri) have developed an Enterprise Systems Architecting framework based on the eight important properties of the enterprise. They include Organization, Strategy, Policy, Processes, Products, Services, Knowledge and Information. Nightingale and Rhodes explain that, "Enterprise Architecting provides the strategies and modeling approaches to ensure that adequate time is spent in developing the possible 'could be' states and evaluating the best alternative given set of desired properties and criteria for the future enterprise system. In case of already established enterprises, the enterprise architecting provides the approach for analyzing and understanding the 'as is' enterprise, and allows the various alternative changes and interventions to be analyzed" [15].Enterprise Transformation provides successful strategies and implementation approaches for transformation of an enterprise from 'as is' to a 'to be' state. Schematic of the enterprise architecting framework is given in Figure 3.

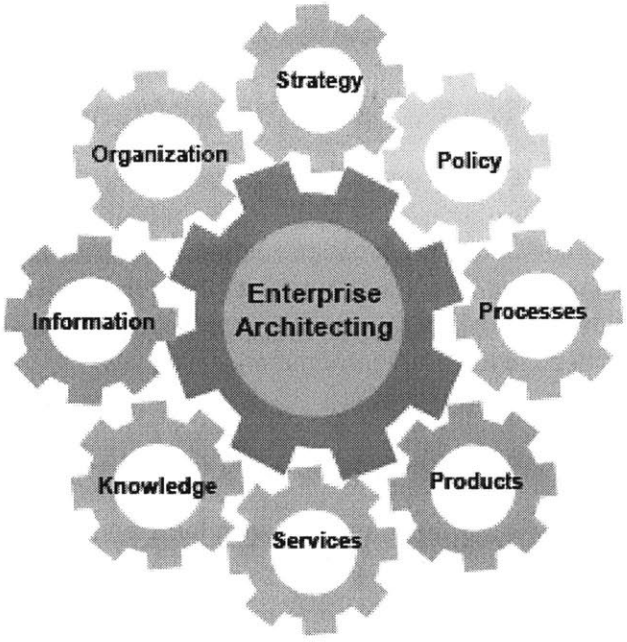

Figure 3 Eight View Enterprise Architecting Framework

Organization: This view represents organizational structure as well as relationships, culture, behaviors, and boundaries between individuals, teams and organizations.

Strategy: This view represents strategic goals, vision, and direction of the enterprise including the business model; enterprise metrics and objectives.

Policy/External Factors: This view represents the external regulatory, political and societal environments in which the enterprise operates.

Processes: This view represents the core processes by which the enterprise creates value for its stakeholders.

Products: This view represents the products developed by the enterprise; key platforms; modular vs. integral architectures, etc.

Services: This view represents services delivered and/or supplied by the enterprise, including in support of products.

Knowledge: This view represents the implicit and tacit knowledge, capabilities, and intellectual property resident in the enterprise.

Information: This view represents the information needs of the enterprise, including flows of information as well as the systems and technologies needed to ensure information availability.

Each view is further characterized by several aspects such as Structure, Behavior, Artifacts, Measures and Periodicity. An overview of these aspects for each view is given in the following table and examples for each view against each aspect are given in Table 2.

	Organization	Strategy	Policy	Process	Products	Services	Knowledge	Information
Structure – Configuration characteristics of the view	Functional versus Matrix Organization, Integrated Product teams	Documented strategic plan	Hierarchy of policy documents	Integrated versus stove piped process design, Global versus local orientation	Modular vs. Integral, commodity vs. custom	Modular vs. integrated, bundled services	Knowledge management process, knowledge repository architecture	IT Architecture, Data warehouse
Behavior-Operational characteristics / Response characteristics	Collaborative vs. Closed, Organizational beliefs and team norms	Leadership style	Agility in responding to policy changes	Repeatability and degree of standardization	Product "ilities" and agility to address new market requirement	Ease of tailoring services	Degree of openness to share knowledge, Not Invented here behavior	Interoperability and accessibility
Artifacts-Items produced to document the performance	Organization chart, Roles and responsibility	List of core values, mission and vision statement	Policy documents	Process value stream maps, process documentation libraries	Prototypes, design documents	Service offering descriptions and documents	Skill sets, best practice documents	Information sharing policies, IT architecture road map and documentation
Measures – The quantification of performance	Productivity measures, employee satisfaction	Market share	Compliance to policies	Productivity and cycle time measures, process compliance measures	Market share, quality, customer satisfaction	Quality, customer satisfaction	Incentive based measures-patents, publications etc.,	Standardization of IT operations, utilization rates
Periodicity – The temporal aspects of definition and deployment	Re-organization update cycles, Instability periods due to lag in response to organization.	Increment in wages, expansion and growth plan	Clock speed of regulatory environment	Process lifespans, frequency of process audits	Product release and revision cycles	Request to delivery time, service cycle times	Refresh rate of knowledge assets	Knowledge Refresh rates, Rate of information flow, Technology update cycles

Table 2 Enterprise Architecting - Detailed View. Source: Enterprise Architecting class notes and lectures

LAI's Enterprise Architecting framework can be used by managers to view business issues through these eight lenses. This will help the managers in identifying and prioritizing some of the most important views which are essential to solve the business issues. This framework can also be used by enterprises to answer some of the key question such as how to identify and prioritize the stakeholder's value proposition, how the enterprises can be designed to deliver best value to stakeholders, what roles does leadership play in architecting enterprise etc. It can also be used to address interactions that happen at

various levels within the enterprise such as internal and external interactions. Three major stages recommended by this framework for enterprise design and transformation include:

- Architecting – Defining Candidate Architectures
- Evaluating – Selecting Preferred Architecture
- Transformation-Realizing new Architecture

3.2 Significance of Enterprise Architecting and Sustainability

Nightingale and Rhodes described that," The global environment of this century as demanding a deeper understanding of national and cultural policies, economies, laws, priorities, and preferences. There is a growing need for enterprises to address integrated multiculturalism, and to apply systems perspectives and solutions toward addressing the key global challenges of sustainable development, including world peace and international security, management of natural resources, health systems, and many others. Within the context of this global environment and the challenges faced, enterprises are increasingly driven to consider an expanded set of factors, for example, the social and ecological impacts of decisions and action. Enterprises face complex interaction of multiple advanced technologies, and embedded intelligence that will allow further automation of complex organizational processes. Growth in international cooperation/merging of defense, information technology, communication, transportation, energy, and many other sectors will result in international extended enterprises developing systems of unprecedented size and complexity. Enterprises are also experiencing an evolution in how the people within an enterprise work together with increased teamwork, distance collaboration, and telecommuting" [15] [19]. Under this context, enterprise architecting helps organizations to align their resources towards achieving goals and mission, where stakeholder engagement is complex and prioritization of issues become important. The holistic framework adapted by enterprise system architecting is well suited for addressing issues such as sustainability that is highly cross functional.

Reduction of greenhouse gases is essentially a system level issue considering the interaction of social, financial and environmental systems. Enterprise Systems Architecting effectively manages the complex interactions prevalent among systems using robust tools and frameworks.

4.0 Strategic Dimensions of Sustainability

This section discusses in detail the three strategic dimensions-Drivers, Actions and Challenges. The drivers, actions and challenges, together define the greenhouse gas profile of the companies and it is unique to individual companies and industry. However, on a collective basis some drivers and challenges are peculiar to specific type of industries. This section explains the rationale behind the chosen drivers, actions and challenges.

4.1 Drivers

It is crucial to understand the drivers that force enterprises to become environmental friendly. Since drivers appear from different stakeholders of the enterprise, drivers can sometimes pull enterprise vision in different directions. Leadership is crucial in performing trade-offs and it is important to choose drivers that impact most and appropriately select important business views suggested by LAI's eight view enterprise architecture framework.

List of key drivers important to reduce carbon footprint of the enterprises are given below. This list of drivers was presented to the survey takers for their responses.

- Regulation demands
- Competitor / Peer Pressure
- Customer Demand
- Supplier Demand

- NGO's demand
- Leadership vision
- Immediate economic benefits
- Branding /Marketing opportunity

4.1.1 Regulation Demands

Regulation demands exist at different levels including local, regional, national and global. United Nations Framework Convention on Climate Change (UNFCCC)'s Kyoto protocol, which is aimed at fighting global warming, is an example for global regulation demand. Kyoto protocol sets binding emission reduction targets for 37 industrialized nations and the European community. Overall these trends add up to an average five percent emissions reduction compared to 1990 levels over the five year period 2008 to 2012 [20].

Under the Treaty, countries must meet their targets primarily through national measures, though the Kyoto Protocol offers them an additional means of meeting their targets by several market based mechanism such as purchasing or trading carbon credits and carbon offsets. Kyoto Protocol places heavier burden on developed nations under the principle of "common but differentiated responsibilities" and it requires all other member countries to give general commitment and thus makes it a truly global major regulation demand [20]. The national level measures as suggested by Kyoto Protocol, to reduce GHG have forced some countries to impose further stringent regulations on some industries and make significant changes in the national level energy and fuel policy. For example European Union has approved a binding biofuels mandate of 10% by 2020 [21]. The United States Environmental Protection Agency's Renewable Fuel Standards (RFS) 2007, requires oil companies to blend renewable fuels and ultimately reduce their dependence on fossil fuels [22]. Some of the

renewable fuels include cellulosic biofuel, advanced biofuels including algae, vegetable oils and biomass based diesel.

Another example of global regulation demand is the fuel efficiency and pollution norms mandated by different countries for automobile emissions. Business expansion through product selling in different geographic regions, automobiles in particular, has become extremely difficult for several companies due to varied and stringent regulation norms. For example, an automobile made in India complying with national emission standards, cannot be exported and used in a European country since the emission norms vary among different countries. Even in the United States, federal emission regulations are different from the regulations mandated by California. This situation creates restrictions on exports and business expansions and it is critical from both business and sustainability points of view. In addition to international and national standards, there are states in several other countries also mandating the emissions and have special rules and regulations for the companies in the state.

4.1.2 Competitor / Peer Pressure

Sustainability offers competitive advantage to companies irrespective of the sustainability framework they follow. Nowadays, business competition landscapes have extended beyond capturing market share and satisfying loyal customers. Companies now also focus on environmental sustainability based on their competitors. First movers in the sustainability arena receive attraction from media and public through right messages, which helps them in building the reputation and brand. Competitors who are not committed to the environment are overshadowed by the leaders who commit to the environment and communicate the right message to the customers. Hence it is imperative for other companies also to contribute for the environment. Companies such Trucost, are offering peer review services to compare the environmental performance of a particular company with their peers [23]. Companies have

also started comparing their performance against competitors and there is a healthy competition for being environmental friendly.

Poor performance in front of peers forces companies to focus for the superior environmental performance. For example, voluntary carbon disclosure projects are helpful for companies to understand their position in comparison with other target companies, not necessarily in the same industry. Blackburn claimed that "Peer and public criticism-can also provide a bit of accountability when the performance is well below expected levels" [24]. Competition and peer pressure also encourages companies to imitate and follow best practices in the industries. Such situations avoid reinventing the wheel and allow companies to adapt the best practices faster.

4.1.3 Customer Demand

A recent survey conducted among 1500 participants by Boston Consulting Group and MIT Sloan Management Review noted that 58% of the survey respondents cited consumer concerns as having a significant impact on their companies related to GHG reduction [25]. The customer's demand can arise in multiple forms such as company's contribution to the environment in the form of carbon footprint reduction or to society or in the forms of charity. Enterprise should become aware of the customer demands in the sustainability front and act accordingly. Like regulation demands, customer demands also vary according to local, regional and national level. For example, the study conducted by Boston Consulting Group(BCG) and MIT Sloan Management Review noted that, "consumer concerns were viewed as a relatively more critical force in sustainability among companies based outside of the United States and Europe" [25]. However, the customer demands can sometimes be confusing to the companies. Customers' Willingness To Pay (WTP) premium prices for environmental friendly products cannot be assumed by the enterprises. Customers many times expect the companies to perform well in the environmental arena, without changing their consumption pattern. Balancing business decisions to

satisfy customer demand and WTP is a critical challenge for the organization's leadership. Some of the challenges in managing customer demand drivers are discussed in section 4.3.

4.1.4 Supplier Demand

In the value chain of the enterprise, supplier and distributors also play a significant role in the overall environmental performance of the enterprise. Wal-Mart, for example, after started rating their suppliers based on their green performance such as energy, waste, water and ethical production has empowered their suppliers to demand similar kind of performance from the suppliers' supplier [26]. The influence of suppliers' over the parent company depends on the size and the leadership position of the supplier. Thus Tier 1 suppliers act as a common link to connect companies, third party suppliers and the major customers, playing an active role in managing the drivers and actions on sustainability front.

4.1.5 NGO's Demand

Non-Governmental Organizations (NGO) and special interest groups can sometimes become a major driving force behind the sustainability initiatives. This is especially true for agriculture and other industries which are directly related with natural resources such as forest and water. Enterprise should consider these entities as their key stakeholders. Strategic partnership with NGOs and special interest groups can help companies in mitigating the unknown risks involved in the sustainability initiative. Wal-Mart identified a team of NGO's, academics, suppliers and regulators to help them design a rating system for suppliers [26]. McKinsey has also involved several NGO's to create the best informed view on carbon abatement measures and their local applicability [27]. Proactive involvement with the NGO's will also help the companies in identifying new business opportunities and expose risks at the earlier stages. Increasing knowledge base and credibility of NGO's, increased understanding of the companies about the benefits of collaboration are empowering NGO's to play a critical role in this socio-technical issues to obtain more control and to demand power as the stakeholders.

4.1.6 Leadership Vision

Most of the thought leaders in various industries have started their sustainability initiatives as early as 1980's when other companies or even regulatory bodies were unaware of the prevailing sustainability issues. For example, Interface, world's largest carpet tile manufacturer, was an early mover in the sustainability arena in 1998 and pioneered the business model of "servicizing" the products by leasing their carpet tiles instead of selling them to consumers, to avoid the sustainability concerns by the landfills created by used carpets [28].To extend the leadership, in 2006, Interface created a separate company called Interface RAISE to deliver peer-to-peer sustainability consulting services to help other industries excel in the environmental performance [29].GE, in 2005, included all of its business practices under its Ecomagination[3] umbrella, addressing sustainability issues in all fronts [30]. The breadth and depth of the sustainability issues addressed by GE through Ecomagination has gained the reputation of "first-class in sustainability" by the survey respondents according to the MIT Sloan and BCG special report [30].

Either through environmentally differentiated products or through 'servicizing' their products, several companies have advanced their environmental performance. Toyota, for example, introduced Prius, the first hybrid electric vehicle in the market, when no other players were thinking about the product and started working on hybrid technologies in 1993 [31]. Other players entered the market only after 10 years of Toyota's dominance in electric car market. Out of all other factors, leadership of the company is most important, particularly for issues such as sustainability. Sustainability cannot be treated as a standalone subject and the issues lie at the intersection of various subjects such as economics, politics, natural science, engineering and law. Addressing such multiple issues needs thought leaders who can

[3] See more at http://www.ecomagination.com/

educate their organizations on sustainability and lead. Though problem solving in sustainability issues are collaborative, without management or top leader's support no organization might succeed in contributing for environment and thus a top-down approach might be critical for addressing such issues.

4.1.7 Immediate Economic Benefits

Addressing sustainability issues in the initial stages offers easy opportunities to be used by companies for immediate economic benefits without much effort. Some of the process improvement techniques, such as lean principles, kaizens and waste management programs etc. applied throughout the enterprise help companies to reduce energy and carbon dioxide equivalent emissions in a sustained way. For example, decreased use of steam and electricity by improving equipment efficiency could be an easy area to reduce GHG and also to reap immediate economic benefits. Identifying energy leaks and excess energy use, mixing or blending of fossil fuel with other renewable fuels, encouraging public transportation for employees, providing incentives for using hybrid cars, use of renewable energy etc., are some of the strategies followed by the companies to improve internal operations. Resource productivity improvement methods are important for companies to realize economic benefits. However, after all the easy actionable items are exhausted, companies need to force themselves to work on harder long term strategic actions. Enterprises should prepare themselves to horizontally deploy the knowledge obtained through process improvement program to all other business units.

4.1.8 Branding / Marketing Opportunity

Being an environmentally superior company provides unique competitive advantage in terms or branding and marketing. Genuine enterprises which are not following Greenwashing practices are well ahead of the competitors in terms of branding. For example, Stony Field, an organic agricultural company, has created a strong brand and reputation among its consumers being sustainability focused company. Thirty-five percent of the respondents in the study conducted by BCG and MIT Sloan

management review have mentioned that improved company image is the significant benefit for pursing sustainability activities [25]. Branding and marketing opportunity increases customer loyalty and such situations can provide tremendous opportunities for companies to generate profits. Toyota for example, in addition to building a brand and loyalty for its renowned quality, created a new segment and customers for its electric hybrid cars. This has created a huge brand and reputation among customers. Interface, the largest carpet tile manufacturer in the world, has created a niche consulting arm called Interface RAISE consulting based on the experiences gathered by them in managing various sustainability issues in their manufacturing and process shops. Such strategies create great marketing opportunities in addition to creating new business segments.

A summary of the drivers discussed above are shown in Figure 4.

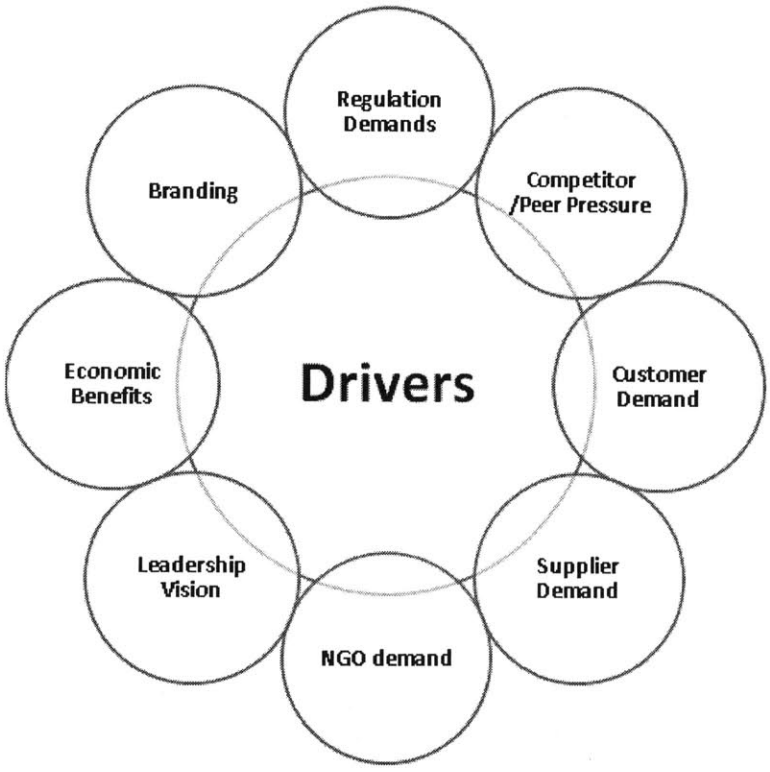

Figure 4 Strategic Dimensions - Drivers

4.2 Actions

Based on the drivers discussed above, the survey asked about some of the actions that are currently followed or preferred by the companies. The actions given in the survey options are given below:

- Improving internal operations
- Revisit supply chain / sourcing strategies
- Business innovations – Products to services
- Environmental product differentiation
- Purchasing carbon offsets

4.2.1 Improving Internal Operations

Improving internal operations is the first step towards reducing GHG for most companies. Organization control and learning from mistakes becomes easier by adapting this strategy. However, companies should be aware of the enterprise level emission created by its business process and should not restrict their actions to internal operations alone. As discussed in section 4.1.1, companies in Kyoto Protocol ratified countries, faced regulatory requirements to reduce their net carbon emission through onsite reductions, purchasing emission permits from other companies that had reduced emissions beyond their required levels, or investing in projects in developing countries that reduce carbon emissions. In addition, many other companies who are not obliged to Kyoto protocol are proactively calculating their carbon footprint. Those companies eventually engage themselves in setting emissions reduction targets, reducing emissions and buying carbon offsets [32]. Lifecycle analysis of the business processes offers great insights about the carbon intensive stages throughout the lifecycle of the products and services [33]. Companies can treat the results of lifecycle assessment as roadmap to mobilize their resources to work on the right problems. As the *Harvard Business Review* recently noted, "Companies that quantify their footprints send a strong signal that they recognize the importance of climate change as a business

risk-and an opportunity" [34]. A list of commercially available lifecycle analysis software and carbon footprint calculators is given in Appendix A.

Greenhouse Gas Protocol defines the boundaries of the enterprise for carbon reduction stages [35].Greenhouse Gas protocol defines its Scope 1 definition as the boundary in which companies reduce their carbon footprint from its internal operations. A brief overview of Scope 1, Scope 2 and Scope 3 emission is presented here [35]:

Scope 1: Direct emissions are those that occur "from sources that are owned or controlled by the reporting entity" including its industrial activities and any on-site energy production. These include four types of sources [36]:

- *Stationary combustion* from the production of electricity, steam, heat or power using equipment in a fixed location.
- *Mobile combustion* in transportation and construction sources including cars, trucks, tractors and airplanes
- *Physical and chemical processes* such as the manufacturing of cement and aluminum
- *Fugitive sources* from unintentional leaks and evaporation, such as methane leakage from natural gas pipelines.

Scope 2: Indirect emissions that result from "activities of the reporting entity but occur at sources owned or controlled by another entity", such as purchased electricity, heat and steam.

Scope 3: Other indirect emissions include all other emissions that associated with a company's activities that are not included in Scopes 1 or 2, such as emissions associated with employee travel; the extraction and processing of raw materials and their transportation to the company; the shipment of the company's products to distribution centers, retailers, and customers; and product disposal. "There is a

broad discretion about which Scope 3 emissions should be included in a business carbon footprint," according to The Carbon Trust [37].

Reduction in Scope 3 emissions provides a systems level solution of decreasing the greenhouse gases from its both upstream and downstream activities. But Scope 3 emissions are calculated less often, in part because of the complexity associated with setting boundaries and the challenges associated with gathering and verifying data [35]. Figure 5 shows the relation between organizational footprint and product footprint.

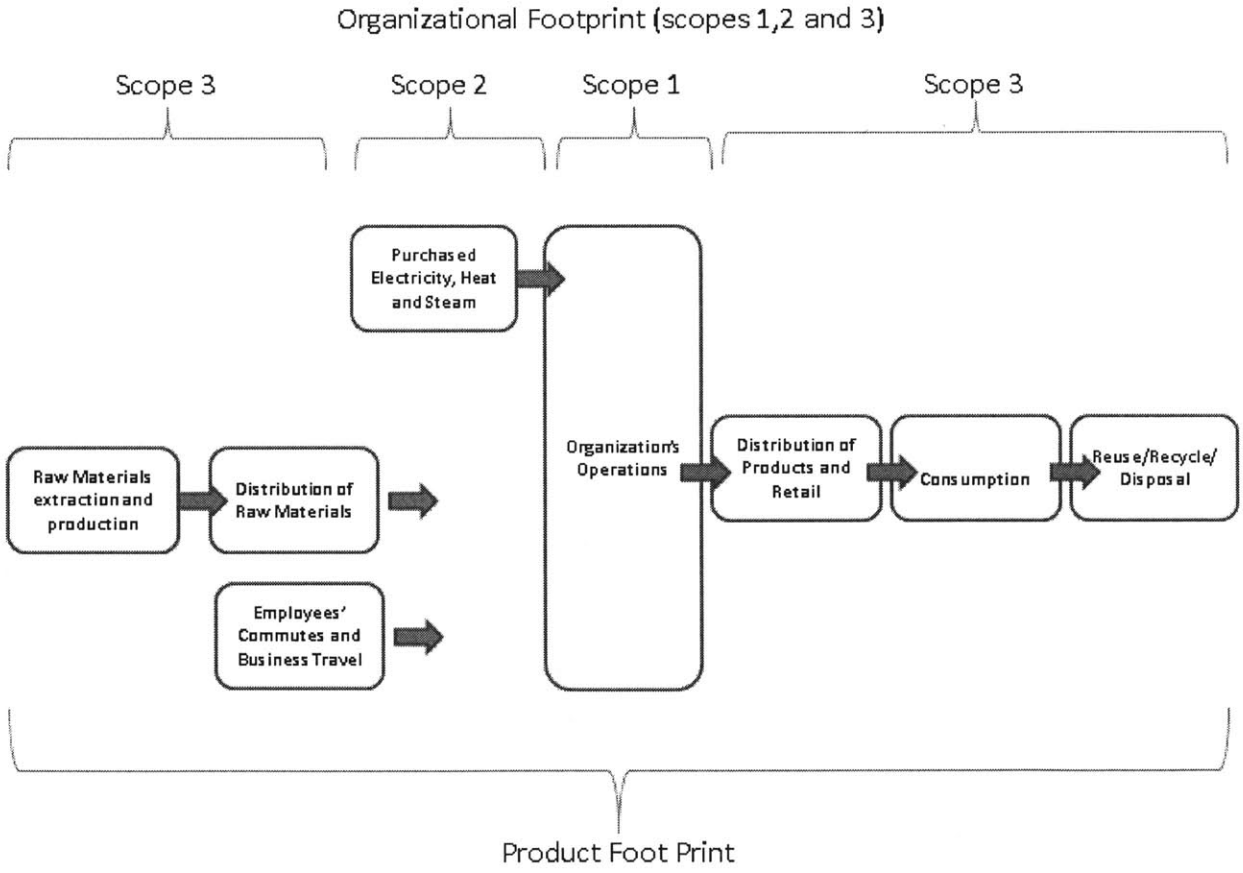

Figure 5 Source: Based on Carbon Trust, "Carbon Foot printing: The Next Step to Reducing Your Emissions Management Guide," April 2010, p3 & Carbon Footprints: Methods and Calculations, Toffel M; Van Sice S; 2011

4.2.2 Revisit Supply Chain / Sourcing Strategies

This strategy fits under Scope 2 and Scope 3 definition of GHG protocol. As discussed above, boundaries that separate Scope 2 and Scope 3 emissions for supply chain can be fuzzy and a clear difference might be very difficult for companies. For some industries, the GHG emission due to its supply network might be more than the contribution from its internal operations. Sourcing from local resources, optimizing supply networks not only help in realizing cost savings, but also in reducing GHG due to lesser energy and fuel consumption.

4.2.3 Business Innovations – Products to Services

Sustainability can be addressed well by improving operational efficiency or providing more environmentally benign products and processes. However, *MIT Sloan Management Review* claimed that while these changes are necessary, they are not sufficient because they do not address consumption levels [38]. Gains in operational efficiency and environment-friendlier technology may even eventually be counteracted by increases in consumption [39].Thus in order to be a truly sustainable society, developed nations must consume less. "This is no small challenge to industrial societies, where consumption has traditionally been an end in itself. Yet companies are often in the best position to help customers reduce consumption – even of their own products. By "servicizing", suppliers may change the focus of their business models from selling products to providing services, there by turning demand for reduced material use into a strategic opportunity" [38].

This new approach has been linked to higher and more stable profits for some companies [40]. In addition, 'servicizing' is more difficult to imitate than just products, it can become a great source of competitive advantage too [41]. According to *MIT Sloan Management Review*, many traditional manufacturing companies, especially those faced with shrinking markets and increased commoditization of their products, are adopting service provision as a new path toward profits, growth and increased

market share" [38]. Some companies that have successfully adopted this practice of servicizing (Xerox, HP, and Interface) are discussed in the following sections.

4.2.4 Environmental Product Differentiation

Environmental concerns can affect customers' willingness to pay for products, the firm's own costs and the risks firms face in trying to create value. In particular, firms that voluntarily choose to reduce their environmental impacts, or to provide environmental benefits beyond the levels required by law, need to find ways to offset the increases in their costs. Some companies have tried to do so through environmental product that enables them to recapture increased costs of environmental protection. Still some other companies try to satisfy both environmental and shareholder value objectives through strategic behavior, raising rivals' costs and thus securing competitive advantage through environmental performance. However, companies should understand the circumstances under which each of them likely to be appropriate. Companies need to understand how their firm's economics are affected by government policy and develop strategies not only for the marketplace but also regarding government policy.

As *California Management Review* noted, "The success of a strategy of differentiating products along environmental lines will depend on the characteristics of the industry structure, business-government relations, and organizational capability that determine corporate success more generally. Some firms have a profitable option to differentiate products or processes along environmental lines; for others, any time spend pursuing such strategies is squandered" [42].

California Management Review also provided three requirements for the companies to succeed by framing strategies based on environmental product differentiation [42]:

- The business must find, or create, a willingness among customers to pay for environmental quality;
- The business must establish credible information about the environmental attributes of its products; and
- Its innovation must be defensible against imitation by competitors.

4.2.5 Purchasing Carbon Offsets

Carbon offsets are a widely discussed mechanism whereby individuals and corporations pay for reductions elsewhere in order to offset their own emissions [43]. Carbon offsets provide a new platform for the companies who cannot effectively reduce their greenhouse gas emissions. Organizations and individuals can purchase carbon credits to offset their pollution or to reap the reputational benefits [44]. There are several options available for companies and individuals to purchase carbon offsets in different carbon markets such as Kyoto Market, non-Kyoto cap-and-trade markets and voluntary markets [44]. However, purchasing carbon offsets from credible sources has become a challenge due to difficulty in assessing and verifying the projects offered by the sponsors.

A summary of the actions discussed above are shown in Figure 6.

Figure 6 Strategic Dimensions - Actions

4.3 Challenges

This section discusses some of the challenges faced by the companies in addressing the sustainability issues. Sustainability is a unique business problem intertwined with social code or ethics, business vision, finance, stakeholder support and many other externalities that the industries cannot control.

4.3.1 Customers' Willingness to Pay

Providing environmentally benign products and services can sometimes increase the cost of the products or services. Depending on the market conditions and consumption pattern, the increase in cost might not be preferred by customers. Willingness To Pay (WTP) for environmentally differentiated

products or services offered by the companies arises in industrial markets if, and only if, the products lower the overall costs to the customer [42]. Environmental differentiation is possible even if all the costs and benefits to the customer are difficult to quantify. WTP is increased in several ways such as providing more value to the customers to compensate for the increase in the prices. WTP is a trade-off between the functional performance and sustainability performance. Luchs, Brower and Chitturi's recent research study [45] highlighted some of the critical aspects of WTP to consider in product design practices and marketing. They are:

1) Designers and marketers must know the minimum threshold of functionality for their target customer segment. This is because consumers will not choose a more sustainable product despite the moral superiority if it does not meet the minimum threshold of functionality; 2) Customers are not willing to pay more for sustainability if it means inferior functionality; 3) Designers should calibrate emotional response of sustainability and functional performance for feelings of guilt, distress, and confidence to create the right level and mix of consumer feelings; 4) Marketers then should design their promotion, pricing, and placement strategy keeping the designed product and the competition in mind.

4.3.2 Resistance of Management and Shareholders

Though management support is necessary for every initiative in the organization, sustainability issues are more disciplinary and require huge management support before it becomes part of the corporate strategy. Successful implementation of environmental improvements requires an integrated approach across the entire organization to be led by higher management. Carbon footprint reduction involves various stakeholders and most importantly it requires management's attention and support. As *California Management Review* noted, "the debate over whether environmental protection poses a threat or opportunity for business will not soon be settled" [46]. Reinhardt explained that "that debate will never be settled, because it has been framed in the wrong terms. Instead of asking whether it pays

to be green we ought to be asking about the circumstances under which it might pay. A business behavior with respect to the environment, like any other aspect of strategy or management, should be considered in the light of the basic economic situations of the business: the structure of the industry in which it competes, its own position within that industry, and its internal organizational capabilities. It is necessary to understand this basic economic context in order to think sensibly about businesses' response to the environmental challenge. Without this understanding, prescribing environmental policies for firms is just sloaganeering " [42]. Unless the economic context could be made clear to shareholders, breaking the trade-off between short term and long term goals by choosing right operational decisions can help to obtain shareholders' support in addressing the environmental issues. Thirty-one percent of the respondents of the MIT Sloan and BCG sustainability survey members indicated that failure to include the role of sustainability as part of corporate strategy is an important challenge faced by organizations as mentioned by the MIT Sloan and BCG research study [25].

4.3.3 Credible Information

Communicating credible information to the customers and other stakeholders is important to gain goodwill and support. Communications related to environmentally positive stories are challenging because of the myriad of assumptions and scientific information. Creating strong incentives to customers to invest in the credible information is a challenge. Association with credible certification agencies and scientific bodies would help companies to communicate the right message to the customers. Corporate Social Responsibility (CSR) and marketing department can focus their efforts in communicating the right message to customers to increase the brand awareness and reputation. General Managers and senior managers can increase the credibility of the environmental benefit information related to its own products and processes to employees. Morsing and Schultz claimed that managers need to move from 'informing' and 'responding' to 'involving' stakeholders in CSR

communication itself. The authors conclude that managers need to expand the role of stakeholders in corporate CSR communication processes if they want to improve their efforts to build legitimacy, a positive reputation and lasting stakeholder relationships [47].

4.3.4 Easy Imitation by Competitors

Imitation by competitors can quickly erode the competitive advantage of the first-mover adopting sustainability practices. As *California Management Review* noted , " The introduction of environmentally differentiated products by a rival, even if it is ultimately unsuccessful, can harm other firms in the industry by eroding margins, creating political and public relations difficult or both" [42]. *California Management Review* also suggested some mechanisms to block potential imitation by the competitors. Relationships that firms have already developed with their customers can be an important mechanism to block imitation. Integration of environmental strategy with the firm's overall corporate image can be a differentiating factor to defend imitation [42]. Environmental positioning is an integral part of the business strategy, not an afterthought [48]. Relying on multiple sources of competitive advantage to create "causal ambiguity" could also be an important factor to maintain the first mover advantage [49].

4.3.5 Expensive Initial Investments

In addition to existing mindset and lack of clear business case of sustainability as the existing challenges suggested by MIT Sloan and BCG research [25], requirement of financial resources is an important deterrent to address sustainability issues. Though process improvement tools such as Six Sigma and Lean principles can help organizations to realize some low-hanging opportunities, major overhauling and retrofit of business models and strategies require capital investments. This kind of situation is critical for small and medium sized enterprises as mentioned by MIT Sloan and BCG report [25].

4.3.6 Insufficient Knowledge / Organizational Awareness

Sustainability is a complex subject and requires up to date and multi-disciplinary scientific knowledge, thus making organizations difficult to cope with the sustainability issues. Sustainability issues and mechanisms to address those are in constant flux and often re-adjusting our mental models and assumptions are important. Some of the knowledge areas that organizations could improve are [25]:

- New strategic frameworks and approaches
- High-level sustainability diagnostic tools
- Expertise in specific domains (Environmental economics, etc.)
- Six Sigma and Lean principles
- Financial tools to evaluate sustainability investments
- External consulting or auditing services
- Sustainability scorecard with clear measurable metrics

A summary of the challenges discussed above are shown in Figure 7.

Figure 7 Strategic Dimensions-Challenges

5.0 Survey Response and Analysis – Automotive Industry

In this research, a survey having questions based on the drivers, actions and challenges and the ranking for architectural views was sent to mid and senior level managers in automotive and information technology industries. The results are compiled, analyzed and presented here. The list of survey questions is presented in Appendix B. There were 20 responses for each of the industry sectors, totaling 40 responses.

When compared to the similar kind of survey conducted by MIT Sloan and BCG [25], this survey was more confined to address the scope of the master's thesis research. Some of the major differences and scope of improvement areas are listed below:

- Number of people surveyed can be increased to achieve consistency
- Survey responders are not segregated as experts and novice
- The breadth of the drivers, actions and challenges are limited. Some aspects such as employees concern, global politics etc. are not considered in this survey

However, to apply and explore the eight view Enterprise Systems Architecting framework and to arrive at candidate architectures, the information revealed by this survey was sufficient for the exploratory purpose of this research.

5.1. Drivers

A summary of results for drivers for GHG reduction is given below in Table 3.

Drivers	Rank
Regulation Demands	**4.3**
Competitor Peer Pressure	3.0
Customer Demand	**3.4**
Supplier Demand	2.1
NGO's Demand	2.1
Leadership Vision	**3.4**
Immediate Economic Benefits	**3.7**
Branding / Marketing Opportunity	3.2

Table 3 Drivers- Survey Response–Automotive Industry

It is evident from the results that the main driver for automotive industry is the regulation demands. The next immediate driver is the economic benefits derived from the sustainability initiatives. Customer

demand and the commitment shown by the leadership are also considered as the most important drivers in the automotive industry. Automobile industry, being a buyer centric one, supplier demand and NGO demands take the least priority according to the survey respondents.

5.2 Actions

A summary of actions based on the survey results is given below in Table 4.

Actions	Rank
Improving Internal Operations	**3.8**
Revisit Supply chain / sourcing strategies	**2.9**
Business Innovations – Products to services	2.6
Environmental Product Differentiation	**3.4**
Purchase Carbon Offsets	2.5

Table 4 Actions-Survey Response-Automotive Industry

From the survey results, it is inferred that improving internal operations, environmental product differentiation and supply chain optimization takes precedence among other available options. Other options such as purchasing carbon offsets did not emerge as the strong indicators for the action to reduce greenhouse gases.

5.3 Challenges

A summary of challenges to reduce GHG is given below in Table 5.

Challenges	Rank
Customer's unwillingness to pay premium prices for environmentally differentiated products	**3.5**
Difficult in getting higher management attention/ Shareholders' resistance	**2.8**
Difficulty in communicating the credibility of environmental friendly products or services attributes to customers	2.6
Easy imitation of your business strategies by competitors thereby eroding the competitive advantage	2.3
Expensive initial investments	**4.1**
Insufficient knowledge / Awareness in the organization	2.7

Table 5 Challenges-Survey Response-Automotive Industry

Expensive initial investments and customer's unwillingness to pay the premium prices in order to get the right returns on the environmental economic context ranks top among the list of other challenges. Also the requirement of management's attention and the shareholders' resistance is considered as one major challenge.

5.4 Other Survey Responses

Thirty percent of the respondents said that they will not help their suppliers to become environmental friendly. However, 100% of the respondents said that they demand their suppliers to be environmental friendly. This clearly shows a lack of integrative approach in addressing the sustainability issues. This situation represents a condition of lack of transparency and knowledge sharing among stakeholders and

this would be a deterrent for companies to make progress in GHG reduction front. Thirty percent of the respondents said that in addressing GHG reduction, they would seek for external help and 70% of the respondents mentioned that they would mobilize their internal resources and increase the work-how knowledge within the organization.

5.5 Ranking of Eight Views

Based on the three dimensions, action, drivers, and challenges, respondents were asked to rate the influence of each of eight architectural views based on their company's current position and with their understanding. The summary of the ranking of the eight views are shown in Table 6.

Architectural view	Ranking importance
Strategy	**3.9**
Policy	3.6
Process	3.6
Product	**4.0**
Service	**3.8**
Knowledge	3.4
Information Technology	2.5
Organization	3.1

Table 6 Rankings of View-Automotive Industry

Products, strategy and service are the three most important views among the eight views. Based on the survey results, gap analysis has been conducted to evolve different candidate architectures.

6.0 Gap Analysis and Candidate Architectures – Automotive Industry

Gap analysis is important to understand the driving forces in the enterprise's environment, internal driven need for change and major strategic issues facing the enterprise [14]. As the framework of Enterprise Systems Architecting suggests three different stages of architecting as discussed in section 3.1, it is important to understand the current "as is" stage and the desired "to be" stage for the organizations in order to develop effective candidate architectures.

Based on the survey response, a matrix showing the relationship between drivers, actions and challenges is shown below in Figure 8. In this case, the actions, mentioned by the survey respondents are assumed as the desired 'to be' stage in which the organizations would be performing the required actions to reduce greenhouse gases. The challenges or barriers, identified by respondents are treated as the 'as is' state of the enterprise. Based on this assumption, gap analysis results are discussed in this section.

6.1 Identified Gaps

Figure 8 depicts six important gaps and relationships identified among the 'as is' stage, drivers (enablers) and the 'to be' stage, as indicated by the numbered dotted lines and arrow. The gaps and relationships need to be identified for the following reasons:

- To leverage drivers for the maximum benefit to realize the desired 'to be' stages
- To reduce the intensity of the challenges by enabling right drivers for the actions
- To derive synergy among drivers so that the implementation process would be easier

The relationships are important to identify the candidate architectures to be developed.

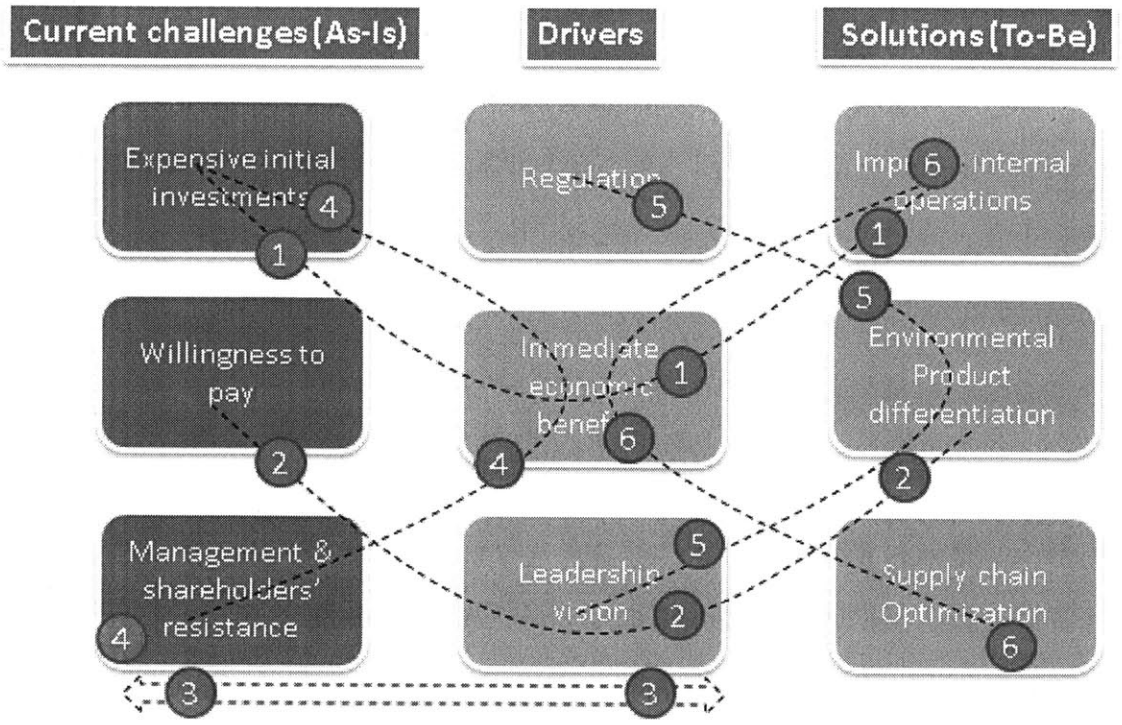

Figure 8 Relationship Matrix -Drivers, Actions and Challenges-Automotive Industry

1) While immediate economic benefits is one of the strong drivers, improving internal operations, is an attractive choice for companies for a desired 'to be' stage. By this method, the expensive initial investments can also be mitigated by the savings obtained from increased operational efficiency. Deploying lean principles and other process improvement programs could help companies in breaking even the investment faster.[4] (Path traced by line number 1)
2) Focusing more on the leadership abilities of the organization could derive the product differentiation concept to include more value (implicit or explicit), so that the customers are not hesitant to pay. For example, Toyota Prius offered additional values such as GPS in the hybrid

[4] See more at http://world-class-manufacturing.com/economy/tpm.htm

vehicle, which were not offered in other vehicles in the initial stages. Such benefits can help customers in changing their mindsets to pay for the products. (Path traced by line number 2)

3) Effective leadership can liaise between management and shareholders to communicate the environmentally positive story of the envisioned 'to be' stage and could win their support. (Path traced by line number 3)
4) The economic benefits could be highlighted among shareholders and management to reduce their resistance for expensive initial investments. (Path traced by line number 4)
5) Regulation can incentivize product differentiation benefits and effective leadership could influence regulators to promote the environmental benefits. This strategy might also help to customers to increase their willingness to pay. (Path traced by line number 5)
6) Improving internal operations could also have a spillover effect on the supply chain operations. Vendors and suppliers can also be benefitted by extending the operational efficiency program. (Path traced by line number 6)

Beside the gaps identified based on the relationship matrix, some other gaps are also identified based on the survey responses are discussed below:

7) While 100% of the survey respondents expect the suppliers to be environmental friendly, only a few of them are ready to extend their hands to help suppliers. This is a serious concern, since reducing greenhouse gases should not be treated as a standalone entity. It is a system level problem that needs to be addressed by all stakeholders. Knowledge transfer and collaborative works among enterprise stakeholders must be encouraged to share best practices to reduce GHG.

6.2 Envisioned Future State

Based on the survey response including the ranking of the eight views, a relationship matrix is developed considering the envisioned future state and the significance of the top three views. The relationship matrix is shown in Figure 9.

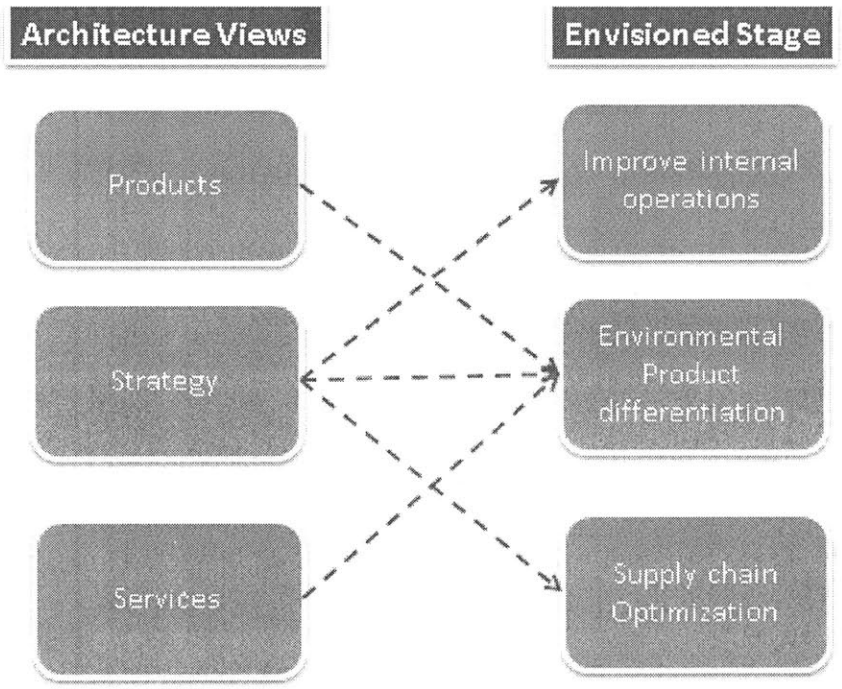

Figure 9 Envisioned Future Stage and Architecture Views-Automotive Industry

The following inferences can be drawn based on the relationship matrix given above:

- Strategy plays an important role in addressing all the three important envisioned stages: Improving internal operations, product differentiation and supply chain optimization.
- Product view is emphasized more to develop environmentally differentiated products
- Though service is not a direct enabler for product differentiation, focusing on services view will help enterprises in adopting new business model such as servicizing products.

However, in order to obtain a holistic perspective based on the eight views, enterprises need to focus on other views too to complement current actions and reach to the 'to be' stage faster. A detailed relationship of all views with respect to 'to be' views is given below in Table 7.

Views	Improving Internal Operations	Product Differentiation	Supply chain sourcing
Products		●●●	
Strategy	●●●	●●●	●●●
Service		●	
Process	●●●	●●	●●●
Policy		●	●
Knowledge	●●●	●●●	●●●
Organization	●●	●●	●●
Information Technology	●		

Table 7 Influence of Architecture Views on Envisioned Future-Automotive Industry

The relationship matrix defines the qualitative relationship between architectural views and envisioned future state. Three- dots indicate high influence of architectural views, whereas two-dots and one-dot indicate medium and low influence on the desired stages. Besides, the dominant views mentioned by respondents, other views such as process, knowledge and organization also play an important role in complementing the actions executed based on other views. The inter-relationship between different views is important for a holistic understanding of the actions to be executed.

6.3 Candidate Architectures

Generating candidate architectures is a mixture of art and science [14]. Nightingale and Rhodes explained that there are several approaches to generate candidate architectures and they are listed below [14].

- Generate first round architectural concepts
    - Identify a set of key attributes for the future state enterprise
    - Use views, soft factors, and out of box thinking to trigger concepts
    - Sketch concepts visually or with simple diagrams
    - Use SWOT and other techniques for qualitative assessment against desired attributes of future state
    - Down-select concepts for pass-thru or combination in next round
- Incorporate creative brainstorming
- Use Heuristic Knowledge [50]
    - Don't assume original statement of problem (or the vision) is right
    - Simplify, simplify, simplify
    - Build in and maintain options as long as possible
- Consider compositional approaches
- Risk taking versus Risk adverse nature of the enterprise
- Stage of enterprise "age" and maturity

Based on the above mentioned criteria, a list of candidate architectures developed for the automotive industry is given below:

Candidate Architecture 1: Combat expensive initial investment by improving internal operations thereby improving resource productivity, to gain management's attention to assess capital.

Candidate Architecture 2: Increase customer Willingness To Pay (WTP) by differentiating the product by adding more value.

Candidate Architecture 3: Win shareholders' support by communicating the benefits of sustainability by benchmarking and demonstrating the benefits.

Candidate Architecture 4: Adapt robust supply chain strategies that will have lesser environmental impact and better economic benefits. Combining this candidate architecture with candidate architecture 1 can provide maximum benefits on both internal and external fronts.

Candidate Architecture 5: Incorporate GHG reduction in the integrated corporate strategy so that all business and operational decisions would be aligned to the corporate strategy [42].

Following the candidate architecture proposals, an alignment matrix is developed based on internal assessments. Alignment matrix is important to emphasize the relationship between the candidate architectures and the eight architectural views, as shown in Table 8 .

	CA -1:Focus on internal operations to gain management's attention to combat initial investments	CA-2: Add more value to the product to increase WTP	CA-3: Increase the credibility of communication to reduce shareholder's resistance and increase management attention	CA-4: Focus on supply chain strategy in addition to improving internal operations	CA-5: Incorporate GHG reduction in the corporate business strategy
Strategy	✓	✓	✓	✓	✓
Product		✓			✓
Service		✓		✓	
Policy			✓		✓
Process	✓			✓	✓
Organization	✓		✓	✓	✓
Knowledge	✓	✓	✓	✓	✓
Information Technology				✓	

Table 8 Candidate Architecture View Alignment-Automotive Industry

Architectural views cannot be developed separately and their organic structure is different when separated and developed individually. The views must be analyzed collectively rather than individually. Interrelationships among enterprise views are very important. Some views directly influence (drive) other views. Some views directly interact with one another and drive performance in both directions, whereas other views serve as the performance enablers. From the above table, it is inferred that knowledge and strategy views are important for all candidate architectures.

6.4 Evaluation of Architectures

Evaluation of architecture involves several methods as explained by Nightingale and Rhodes [14]. Some of these are listed below:

- Weighted criteria (typically" ilities"-like)
- Weighted criteria with sub-criteria for each criteria
- Pugh process –compare candidates as better/same/worse than a baseline architecture
- Evaluation against formal business strategies/metrics
- Evaluation against other enterprises or benchmarks

Evaluation criteria are also dependent on the stakeholders involved. In this thesis, the important stakeholders considered are shareholders, management, customers and suppliers.

6.4.1 Ilities

Systems Architecting defines possibilities for an enterprise having desired properties, often characterized as "ilities" [14]. The "ilities" act as non-functional requirements used to evaluate the performance of a system.[5] Some of the important ilities considered for evaluating the candidate architectures are listed below. However, a final selection of candidate architecture will be based on the current situation of the company and on more interaction with survey responders. The ilities selected to evaluate the candidate architectures are:

1) **Flexibility** – The ability of the enterprise to align its business strategies to reduce greenhouse gas emissions based on current trends and situations.

[5] See a list of "ilities" at http://en.wikipedia.org/wiki/List_of_system_quality_attributes

2) **Adaptability** – This property denotes enterprise's openness to adapt best practices and its focus on acquiring new skills and knowledge to address sustainability issues.
3) **Innovativeness** – This property denotes creative capacities of organization to introduce innovations in its business and operations practice.
4) **Collaborativeness** – This property denotes the knowledge sharing practices and collaborative nature of the organizations to deal with other stakeholders to share the best practices.
5) **Learnability** – This property determines the preparedness and enthusiasm of the organization to learn new information and insights about GHG reduction. Due to the advanced research and engineering efforts, mental models and insights about sustainability issues are always questioned. Organizations need to develop this property to strengthen their knowledge view.

More ilities could be identified to extend the five ilities listed above.

6.4.2 Evaluation Criteria

Some of the key evaluation criteria based on the ilities discussed above are given below:

Flexibility:

- Does the proposed candidate architecture (CA) improve response to changing regulation or policy decisions?
- Does the proposed CA readily allow changing strategies to achieve the goals?

Adaptability:

- Does the proposed CA allow enough agility for the enterprise to execute actions?
- Does the proposed CA allow the employees to improve their knowledge to adapt best practices?

Innovativeness:

- Does the proposed architecture facilitate innovative products and solutions?
- Does the proposed CA allow taking risks based on the innovative business operations?

Collaborativeness:

- Does the proposed CA allow the enterprise to collaborate effectively with stakeholders?
- Does the proposed CA allow delivering stakeholders' expectations at the right cost?

Learnability:

- Does the proposed CA identify and support the learning capacity of the enterprise?
- Does the proposed CA effectively support knowledge sharing practices with other stakeholders?

A generic framework to evaluate candidate architectures based on the ilities is shown in Figure 10.

					Candidate Architectures				
			Key Questions		CA-1	CA-2	CA-3	CA-4	CA-5
Key Ilities	Flexibility	Weighing Factor	Does the proposed CA improve response to changing regulation or policy decisions?	Weighing Factor					
			Does the proposed CA readily allow changing strategies to achieve the goals?	Weighing Factor					
	Adaptability	Weighing Factor	Does the proposed CA allow enough agility for the enterprise to execute actions?	Weighing Factor					
			Does the proposed CA allow the employees to improve their knowledge to adapt best practices?	Weighing Factor					
	Innovativeness	Weighing Factor	Does the proposed architecture facilitate innovative products and solutions?	Weighing Factor					
			Does the proposed CA allow taking risks based on innovative business operations?	Weighing Factor					
	Collaborativeness	Weighing Factor	Does the proposed CA allow the enterprise to collaborate effectively with stakeholders?	Weighing Factor					
			Does the proposed CA allow delivering stakeholders' expectations at the right cost?	Weighing Factor					
	Learnability	Weighing Factor	Does the proposed CA identify and support the learning capacity of the enterprise?	Weighing Factor					
			Does the proposed CA effectively support knowledge sharing practices with other stakeholders?	Weighing Factor					

Figure 10 Candidate Architecture Evaluation Criteria – Automotive Industry

Each of the ilities is weighted as well as the sub-criterion questions are also weighted. The highest weighted average figure determines the candidate architecture to be selected for transformation plan. However, in this case, the weighing factors and the key questions under each ilities are dependent on the company's maturity level, current financial conditions, and other resources. Deciding on weighting factors and other key questions under each of ilities requires extensive involvement of enterprises. Selection of one particular candidate architecture for the sector of companies would be stretching. However, with further discussion and involvement with key personnel of individual companies, robust evaluation criteria can be built to select the best fit candidate architecture.

7.0 Survey Response and Analysis – Information Technology Industry

Similar to survey response from the automotive industry, the responses from information technology industry are discussed and analyzed here.

7.1 Drivers

A summary of results for drivers for GHG reduction is given below in Table 9.

Drivers	Rank
Regulation Demands	2.4
Competitor Peer Pressure	3.0
Customer Demand	2.9
Supplier Demand	1.4
NGO's Demand	1.0
Leadership Vision	**4.2**
Immediate Economic Benefits	**4.6**
Branding / Marketing Opportunity	**3.8**
Climate Change threats	2.0

Table 9 Drivers-IT Industry response-IT Industry

From the above table, we infer that leadership vision, immediate economic benefits and branding / marketing opportunities to increase competitive differentiation are the top three important drivers for the information technology industry.

7.2 Actions

A summary of results for actions to reduce GHG is given below in Table 10.

Actions	Rank
Improving Internal Operations	**4.4**
Revisit Supply chain / sourcing strategies	1.9
Business Innovations – Products to services	**3.1**
Environmental Product Differentiation	**2.6**
Purchase Carbon Offsets	2.3

Table 10 Actions- IT Industry

From the above table, it is inferred that improving internal operations, introducing new business innovations and environmental product differentiation are the top three actions preferred by the survey respondents. Xerox and HP pioneered in introducing innovative services and products to reduce material and energy use. Xerox's Managed Print Services helps clients meet sustainability goals by reducing paper use, decreasing power use, and eliminating landfill waste [51].Similarly HP's Managed Enterprise Solutions help organizations imaging and printing environment to reduce costs and improve environmental sustainability [52]. Flurry of ENERGY STAR[6] qualified products in the recent years, demand companies to produce environmentally differentiated products to maintain the competitive

[6] ENERGY STAR is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy helping us all save money and protect the environment through energy efficient products and practices. See more at http://www.energystar.gov/index.cfm?c=about.ab_index.

advantage. Competition to provide better products pushes the technology frontiers of the companies to produce environmental friendly products ranging from display screens to enterprise servers.

7.3 Challenges

A summary of challenges to reduce GHG is given below in Table 11.

Challenges	Rank
Customer's unwillingness to pay premium prices for environmentally differentiated products	**3.3**
Difficult in getting higher management attention/ Shareholders' resistance	2.7
Difficulty in communicating the credibility of environmental friendly products or services attributes to customers	2.3
Easy imitation of your business strategies by competitors thereby eroding the competitive advantage	2.8
Expensive initial investments	**3.6**
Insufficient knowledge / Awareness in the organization	**3.6**

Table 11 Challenges – IT Industry

From the survey response, lack of domain knowledge in sustainability and greenhouse gas reduction methods, expensive initial investments and customer's unwillingness to pay premium prices are identified as top three challenges faced by the respondents in IT industry.

7.4 Other Survey Responses

Unlike automotive industry, IT industry survey conveys that 100% of responders are interested in helping their suppliers to reduce greenhouse gas emissions. The response also says that a majority of

them are ready to compare themselves with their peers and they are comfortable with sharing their performance and results on the carbon footprint reduction. Fifty-six percent of the respondents conveyed their willingness to get help from external agencies.

7.5 Ranking of Eight Views

Based on the three dimensions, action, drivers, and challenges, respondents were asked to rate the influence of each of eight architectural views based on their company's current position and with their understanding. The summary of the ranking of the eight views are shown in Table 12.

Architectural view	Ranking importance
Strategy	**4.4**
Policy	3.0
Process	**3.8**
Product	2.2
Service	**3.0**
Knowledge	**3.0**
Information Technology	2.6
Organization	2.9

Table 12 Ranking of Views-IT Industry

From the rankings, it is inferred that strategy, process, service and knowledge views are the most important views for the IT industry.

8.0 Gap Analysis and Candidate Architectures- IT Industry

8.1 Identified Gaps

Figure 11 depicts seven important gaps and relationships identified among the 'as is' stage, drivers (enablers) and the 'to be' stage. Numbered dotted lines and arrows represent significant gaps and relationships identified among the challenges, drivers and solutions.

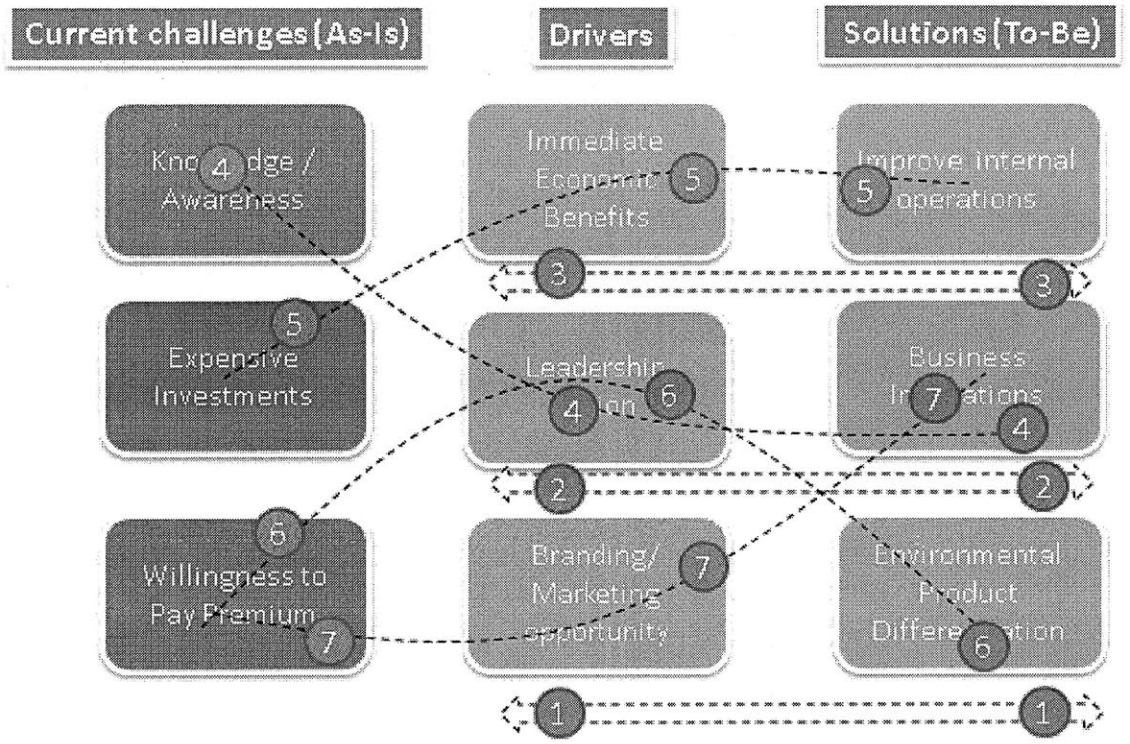

Figure 11 Relationship Matrix-Drivers, Actions and Challenges–IT Industry

Some of the identified gaps based on the relationship diagram are discussed below:

1) Given that branding/ marketing opportunity as an important enabler, product differentiation strategy can be conceptualized as significant competitive advantage. (Path traced by line number 1)

2) Business innovations and leadership vision together form an important combination. Xerox and HP pioneered this approach by servicizing their products in order to achieve resource efficiency thus reducing the carbon footprint throughout their operations [51] [52]. (Path traced by line number 2)
3) As identified from the automotive industry responses, immediate economic benefits can be realized by improving internal operations. (Path traced by line number 3)
4) Lack of knowledge/awareness needs to be addressed by top management in order to introduce business innovations. (Path traced by line number 4)
5) Expensive initial investments can be mitigated by realizing economic benefits by improving internal operations. (Path traced by line number 5)
6) Willingness to pay could be managed by providing value added environmentally differentiated product driven by committed leadership. (Path traced by line number 6)
7) Unwillingness to pay premium or increase in cost can be offset by increasing the company brand and reputation by adapting business innovations. (Path traced by line number 7)s

8.2 Envisioned Future State

Based on the survey response including the ranking of the eight views, a relationship matrix is developed considering the envisioned future state and the significance of the top three views as shown in Figure 12.

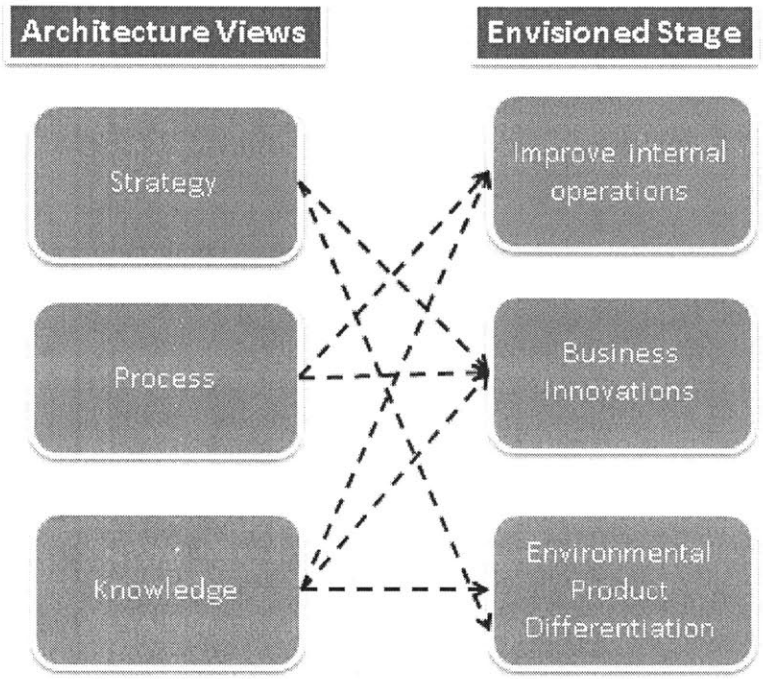

Figure 12 Envisioned Future Stage and Architecture Views-IT Industry

From Figure 12 we can infer following important relationships:

- Strategy view is important to nurture business innovations and to develop environmentally differentiated products in order to gain competitive advantage.
- Focus on the process view of the enterprise is crucial to improve internal operations and to develop innovative business services. As most of the IT industry operations are focused on the enterprise owned assets, focusing on improving internal operations needs a robust support from the process view. Green Building certification, electricity and water management for power intensive servers and data operation centers are some of the important areas for IT companies to focus.
- Knowledge is a horizontal skill that runs across all envisioned future stage. Though organizations such Google and Yahoo have pioneered the efficient use of electricity and renewable sources,

many other smaller companies need to enhance their knowledge on the subject of greenhouse gases in order to achieve superior environmental performance. Knowledge is a bedrock foundation for enterprises in order to achieve all the three envisioned stages.

However, in order to obtain a holistic perspective based on the eight views, enterprises need to focus on other views also to complement current actions to reach the 'to be' stage faster. The interrelationships of views are critical in order to understand the future execution plan. A detailed relationship of all views with respect to 'to be' views is given below in Table 13.

Views	Improving Internal Operations	Business Innovations	Product Differentiation
Products		●●●	●●●
Strategy	●●●	●●●	●●●
Service		●●●	●
Process	●●●	●●●	●●
Policy		●	●
Knowledge	●●●	●●●	●●●
Organization	●●	●●●	●●
Information Technology	●	●●	●●

Table 13 Influence of Architecture Views on Envisioned Future-IT Industry

The relationship matrix defines the qualitative relationship of architectural views with the desired 'to be' stage. Three-dots indicate high influence of architectural views, whereas two-dots and one-dot indicate medium and low influence on the desired stages. Besides, the dominant views mentioned by respondents, other views such as information technology and organization do play an important role in

complementing the actions executed based on other views. The inter-relationship between different views is important for a holistic understanding of the actions to be executed.

8.3 Ilities and Candidate Architectures

Based on the discussion mentioned in section 6.4.1, the evolution of ilities and candidate architectures are reviewed in this section. The same list of ilities as discussed in 6.4.1 can be directly applied to the information industry sector also. The list of ilities is repeated here:

1) **Flexibility** – The ability of the enterprise to align its business strategies to reduce greenhouse gas emissions based on current trends and situations.
2) **Adaptability** – This property denotes enterprise's openness to adapt best practices and its focus on acquiring new skills and knowledge to address sustainability issues.
3) **Innovativeness** – This property denotes creative capacities of organization to introduce innovations in its business and operations practice.
4) **Collaborativeness** – This property denotes the knowledge sharing practices and collaborative nature of the organizations to deal with other stakeholders to share the best practices.
5) **Learnability** – This property determines the preparedness and enthusiasm of the organization to learn new information and insights about GHG reduction. Due to the advanced research and engineering efforts, mental models and insights about sustainability issues are always questioned. Organizations need to develop this property to strengthen their knowledge view.

Candidate Architecture 1: Mobilize organization resources to introduce innovative business practices to increase resource productivity and to change the consumption pattern of consumers to reduce greenhouse gases.

Candidate Architecture 2: Focus on improving internal operations to reduce carbon footprint.

Candidate Architecture 3: Increase brand promotion and market presence by communicating the carbon focused business strategy and operations to win premium prices and competitive differentiation.

Candidate Architecture 4: Focus on purchasing carbon offsets in addition to focusing on improving internal operations and energy use.

Candidate Architecture 5: Increase employee's knowledge and awareness in the carbon reduction area and increase employee participation in the day to day operations to synergize carbon reduction efforts.

Following the candidate architecture proposals, a relationship between the candidate architectures and the eight architectural views is developed, as shown in Table 14.

	CA -1:Mobilize organization resources to introduce business innovations to reduce carbon footprints	CA-2: Focus on internal operations to reduce the carbon footprint	CA-3: Increase brand promotion and gain goodwill by highlighting green practices	CA-4: Focus on purchasing carbon offsets in addition to focusing on improving internal operations	CA-5: Focus on improving organization knowledge in the sustainability areas and synergize contributions
Strategy	✓	✓	✓	✓	✓
Product	✓				
Service	✓	✓			
Policy	✓		✓	✓	✓
Process	✓	✓	✓	✓	✓
Organization	✓		✓		✓
Knowledge	✓	✓		✓	✓
Information Technology	✓				

Table 14 Candidate Architecture View Alignment-IT Industry

From the above table, it is inferred that knowledge and strategy views are important for all candidate architectures. A similar candidate architecture evaluation matrix as discussed in 6.4.2 is given in Figure 13.

			Key Questions		Candidate Archietctures				
					CA-1	CA-2	CA-3	CA-4	CA-5
Key Ilities	Flexibility	Weighing Factor	Does the proposed CA improve response to changing regulation or policy decisions?	Weighing Factor					
			Does the proposed CA readily allow changing strategies to achieve the goals?	Weighing Factor					
	Adaptability	Weighing Factor	Does the proposed CA allow enough agility for the enterprise to execute actions?	Weighing Factor					
			Does the proposed CA allow the employees to improve their knowledge to adapt best practices?	Weighing Factor					
	Innovativeness	Weighing Factor	Does the proposed architecture facilitate innovative products and solutions?	Weighing Factor					
			Does the proposed CA allow taking risks based on innovative business operations?	Weighing Factor					
	Collaborativeness	Weighing Factor	Does the proposed CA allow the enterprise to collaborate effectively with stakeholders?	Weighing Factor					
			Does the proposed CA allow delivering stakeholders' expectations at the right cost?	Weighing Factor					
	Learnability	Weighing Factor	Does the proposed CA identify and support the learning capacity of the enterprise?	Weighing Factor					
			Does the proposed CA effectively support knowledge sharing practices with other stakeholders?	Weighing Factor					

Figure 13 Candidate Architecture Evaluation Criteria-IT Industry

Based on the weighted scores gained by the candidate architectures, the best suited candidate architectures can be chosen by the industries to execute transformation plan.

9.0 Transformation Plan

After selecting the right candidate architecture that best suits the envisioned future stage of the enterprise, a robust transformation plan to implement the selected candidate architecture is essential. Transformation stage is where the architecture is realized. Some of the transformation challenges faced by organizations are given below [53].

- **Growth:** Increasing Impact

- **Value:** Enhancing Relationships of Processes to Benefits & Costs
- **Focus:** Pursuing Opportunities & Avoiding Diversions
- **Change:** Competing Creatively While Maintaining Continuity
- **Future:** Investing in Inherently Unpredictable Outcomes
- **Knowledge:** Transforming Information into Insights to Programs
- **Time:** Carefully Allocating Organization's Scarcest Resource

Transformation planning for the enterprise based on the candidate architectures involves various managerial skills as explained by Nightingale and Rhodes [14].

- Determine how the architectural selection and evolution needs to be communicated
- Provide incentives aligned with stakeholder values
- Ensure needed people/organizational capabilities to transform
- Develop structure and governance process
- Communication leadership
- Align performance metrics with architecture (also with vision strategy)
- Plan for removal of obsolete/extraneous enterprise artifacts

Transformation plans determine the organizational capabilities and management abilities of the enterprise to achieve the desired 'to be' stages. However, transformation plans needs to be developed with clients after communicating the selected candidate architectures. Enterprise Architects draw on inductive reasoning and heuristics to develop an enterprise concept [14]. Heuristics often play an important role in determining and evaluating candidate architectures also. Heuristics are often referred as an important tool in art of systems architecting [54].

10.0 Comparison of Industry GHG Profiles

The dimensions of greenhouse gas reduction strategies – drivers, actions and challenges, in addition to the importance of views together define the 'greenhouse gas profile' of the companies and this section discusses some of the similarities and differences in the GHG profiles of both industries. The current 'greenhouse gas profile' of the companies will decide the future course of action considering the externalities that affect the prevailing business model of the companies.

10.1 Drivers

Automotive Industry	IT Industry
Regulation Demands	Economic Benefits
Economic Benefits	Leadership vision
Leadership vision	Branding / Marketing Opportunity
Customer demand	

Table 15 Drivers-Comparison

Table 15 above shows the top drivers for both the industries. Realization of economic benefits and the futuristic vision of the leadership are common drivers for both the industries. Branding and marketing opportunity also drives the sustainability initiative for the IT industry. Customer demand is considered as one of the important drivers for automotive industries, where as it is not ranked by responders from IT industry.

10.2 Actions

Automotive Industry	IT Industry
Improving Internal Operations	Improving Internal Operations
Environmentally differentiated products	Business Innovations-Products to Services
Supply chain Optimization	Environmentally differentiated products

Table 16 Actions-Comparison

Both industries share two common actions to reduce GHG emissions. They are: Improving internal operations and introducing environmentally differentiated products. Irrespective of the business nature of the industries, environmental friendly products and improving resource productivity are preferred by both industries. The supply-centric nature of automotive industry and dependency on various vendors spread throughout the world, force automotive companies to focus on effective and optimum use of the supply network to derive maximum economic benefits while reducing environmental burden. This condition presents more challenges to reduce Scope 3 emissions for supply centric organizations, whereas for IT industries Scope 3 emissions are limited. Some of the Scope 3 emission reduction agenda executed by software companies include reducing employee travel and changing the commuting pattern of the employees, encouraging them to use public transportation [55].

10.3 Challenges

Automotive Industry	IT Industry
Expensive Initial Investments	Expensive Initial Investments
Customers' unwillingness to pay premium	Insufficient knowledge/awareness in the organization
Management attention/ Shareholders' resistance	Customers' unwillingness to pay premium

Table 17 Challenges-Comparison

Initial investments and customers' unwillingness to pay premium for the predictable or unpredictable increase in the price of the products or services are the important challenges faced by both industries. Combating the increase in cost, while maintaining environmental superiority is the biggest challenge faced by both industries. Though management support is important for both industries to execute the actions effectively, survey responders from automotive industry are more concerned about the lack of management support. Increasing employee awareness and knowledge about the greenhouse gas reduction strategies is also considered as one of the important challenges for the IT industry. Increasing

awareness is important to win employees' goodwill and to build systematic frameworks to increase sustainability efforts, thus avoiding ad-hoc action plans.

10.4 Architectural Views

Automotive Industry	IT Industry
Strategy	Strategy
Product	Process
Service	Service
	Knowledge

Table 18 Architectural Views-Comparison

Strategy is selected as the most important view for both of the industries. As *California Management Review* noted, environmental positioning is an integral part of the business strategy, not an afterthought [42]. Irrespective of the type of business, strategy forms an important role. Some of the gaps identified based on the views and the envisioned future states are shown in Table 7 and Table 13. Table 7 and Table 13 also highlight the significance of other views to achieve the desired 'to be' stage. Process view is important for automotive industries to focus on internal operations to reduce greenhouse gases. However, the importance of the process view is not emphasized in the survey response. Service view is important for industries when 'servicizing' products forms a critical aspect of the greenhouse reduction strategies. Though it is appropriate for IT industries, service view is overemphasized in automotive industry response. Significance of knowledge view is correctly identified by IT industry responders, admitting lack of knowledge and awareness among employees, a major barrier to expedite sustainability efforts.

11.0 Future Research Scope

Consideration of changes in sustainability context and linking Enterprise Architecture with Balanced Scorecard are some of the research areas that can be explored to further advance this thesis. Sustainability issues are not constant and often influenced by new scientific information, changing assumptions and new mental models to understand and act [25]. Epoch-Era Analysis is important for enterprise architects to understand when the contexts and mission change. In order to continue to deliver value, a successful system must dynamically overcome changing contexts and needs [14] [56]. Ross and Rhodes define that "Epoch-Era Analysis is a time-based analysis method used for conceptualizing system timelines using natural value centric timescales wherein the context itself defines the timescales" [57]. Epoch-Era Analysis has been applied to evaluation of technological systems as a visualization/communication approach and also more rigorously in tradespace exploration [58]. According to the authors, "The approach has the potential to enable the enterprise designers to think in a more continuous and anticipatory manner in a world that demands an enterprise match the cadence of a changing environment" [56]. Epoch-Era Analysis is a new approach that addresses the need to consider systems and their delivery of value to stakeholders in context of a changing world. "With Epoch-Era Analysis, the system lifespan is divided in to a series of epochs, defined as time periods when significant needs and context are fixed. Multiple consecutive epochs can be strung together to create an era, or scenario, which represents a long-run view of the changing systems needs and context. Path analysis, across a series of epochs, an era, can then identify system evolution strategies that provide continued high value delivery to the stakeholders" [56].

"Balanced Scorecard" is used for motivating and measuring business unit performance [59]. It is also a management tool that supports the successful implementation of corporate strategies. Recently there have been many research papers published to link sustainability efforts with corporate strategy using

balanced scorecard. "By linking operational and non-financial corporate activities with causal chains to the firm's long-term strategy, the Balanced Scorecard supports the alignment and management of all corporate activities according to their strategic relevance. The Balanced Scorecard makes it possible to take into account non-monetary strategic success factors that significantly impact the economic success of a business. The Balanced Scorecard is thus a promising starting-point to also incorporate environmental and social aspects into the main management system of a firm. Sustainability management with the Balanced Scorecard helps to overcome the shortcomings of conventional approaches to environmental and social management systems by integrating the three pillars of sustainability into a single and overarching strategic management tool" [60]. Enterprise Systems Architecting can also play in active role in mixing of financial and non-financial measures such as sustainability efforts and carbon footprint in the balanced score card. In fact, companies such as Trucost have determined the cost of carbon dioxide equivalent emissions in terms of money, thus attaching financial metrics with sustainability efforts [23] . The versatility and universality of Enterprise Systems Architecting could help in advancing the frontiers of the balanced scorecard to involve innovative measures to determine the financial and environmental performance of enterprise.

Appendix A

List of Lifecycle Analysis Software:

Software / Model	Vendor
BEES	NIST Building and Fire Research Laboratory
Boustead Model	Boustead Consulting
CMLCA	Center for Environment Science
Dubo-calc	Netherlands Ministry of Transport, Public Works and Water Management
Ecoinvent	Swiss Center for Lifecycle Inventories
Eco-Quantum	IVAM
EDIP PC-Tool	Danish LCA Center
eiolca.net	Carnegie Mellon University
Environmental Impact Indicator	ATHENA Sustainable Materials Institute
EPS 2000 Design System	Assess Ecostrategy Scandinavia AB
GaBi	PE Europe GmbH and ICP University of Stuttgart
GEMIS	Oeko-Institute
GREET	Argonne National Laboratories
IDEMAT	Delft University of Technology
KCL-ECO	KCL
LCAIT	CIT Ekologik
LCAPIX	KM Limited
MIET	Center of Environmental Science
REGIS	Sinum AG
Simapro	PRe consultants
Spine@CPM	Chalmers
SPOLD	The Society for Promotion of Life-cycle Assessment
TEAM	Ecobalance
Umberto	ifu Hamburg GmbH

List of online Carbon Footprint Calculators:

	Online Web Address
Personal Footprint Calculators	
Global FootPrint Network	www.footprintnetwork.org/en/index.php/GFN/page/calculators/
The Nature Conservancy	www.nature.org/greenliving/carboncalculator/
World Wildlife Fund	www.wwfmaps.org/CC/carbon_calc.php
U.S. Environmental Protection Agency	www.epa.gov/climatechange/emissions/ind_calculator.html
Organizational Footprint Calculators	
Carbon Fund	http://www.carbonfund.org/Calculators
Terrapass	www.terrapass.com/business/
University of California, Berkeley: Cool Climate Project	www.coolclimate.berkeley.edu/uscalc
U.S. Environmental Protection Agency	www.epa.gov/climateleaders/resources/inventory-guidance.html

Appendix B

Summary of survey questions:

2. What drives your company,client or industry to be competitive on GHG reduction? Highest rank indicates strongest influence.

	Rank
Regulation Demands	
Competitor / Peer Pressure	
Customer Demand	
Supplier Demand	
NGOs' demand	
Leadership vision	
Immediate economic benefits (such as reduced energy use etc.)	
Branding / Marketing Opportunity	

3. Based on the drivers identified in question no 2, what actions do you believe that are most suitable for your company,client or industry in general to reduce GHG?Please rank them. (Some options may not be relevant to your industry structure)

Notes 1: Improving Internal Operations: Some of the tools/methodologies followed by different industries to combat GHG reduction and landfills are: Lean deployment, process optimization, Green Design, Green chemistry, Zero waste program, Industrial ecology,Life cycle assessment studies, Improving resource productivity, Energy use optimization, Use of energy from renewable sources,fuel efficiency of company fleets, etc.

Notes 2: "Servicizing" is the new approach in the industry to change the focus of the business model from selling products to providing services, thereby turning demand for reduced material use into a strategic opportunity.

Notes 3: The main idea is to position the products as environmentally preferable, with the idea of capturing price premium. Think about Toyota Prius-Electric Hybrid vehicle,Energy star certified product etc.

Notes 4: "A carbon offset is a certificate representing the reduction of one metric ton (2,205 lbs) of carbon dioxide emissions, the principal cause of global warming. Although complex in practice, carbon offsets are fairly simple in theory. If you develop a project that reduces carbon dioxide emissions, every ton of emissions reduced results in the creation of one carbon offset. Project developers can then sell these offsets to finance their projects.

There are hundreds of different types of carbon reduction projects. For example, a wind farm generates clean energy, which reduces carbon emissions from coal-burning power plants. In order to finance its operations, a wind farm can sell these reductions in the form of carbon offsets."(Source:http://www.terrapass.com/about/how-carbon-offsets-work.html)

However, the value of purchasing carbon offset depends on the risk worthiness of the project in which the money is invested. For example, if the wind power project is cancelled then the benefits of GHG reduction cannot be realized.

	Rank
Improve Internal Operations (See Notes 1above)	
Revisit Supply chain/ sourcing strategies	
Business Innovations - Product to Services (See Notes 2 above)	
Environmental Product Differentiation (See Notes 3 above)	
Purchase Carbon Offset (See Notes 4 above)	

4. What are the potential barriers that can impede your actions to achieve environmental performance, for your company,client or industry?

	Rank
Customer's willingness to pay premium prices for environmental performance	
Difficulty in getting higher management's attention / Shareholders' resistance	
Difficulty in communicating the credibility of environmental friendly products or services attributes to customers	
Easy imitation of your business strategies by competitors thereby eroding the competitive advantage	
Expensive initial investments	
Insufficient knowledge / awareness in the organziation	

5. Are you comfortable with comparison to other companies in your industry for environmental performance?

- Yes
- No

6. Will you help your suppliers to become environmental friendly?

- Yes
- No

7. Will you demand your suppliers to be environmental friendly?

- Yes
- No

8. What will you choose to improve the environmental performance further?

- Work with external agencies
- Improve in-house knowledge and act

9. With respect to the Eight view Architecture explained above, from your opinion, what view is most important for your company or client in order to achieve better environmental performance?

	Rank
Strategy	
Policy	
Process	
Product	
Service	
Knowledge	
Information Technology	
Organization	

Bibliography

[1] "EIO LCA," Carnegie Mellon University, [Online]. Available: http://www.eiolca.net/Method/eio-lca-method.html. [Accessed 15 December 2011].

[2] J. D. Marshall and M. W. Toffel, "Framing the Elusive Concept of Sustainability: A Sustainability Hierarchy," vol. 39, no. 3, pp. 673-682, 2005.

[3] J. Elkington, Cannibals with Forks: The Triple Bottom Line of 21st Century, Gabriola Island, BC: New Society Publishers, 1998.

[4] C. McDonald and W. Norman, "Getting to the bottom of the "triple bottom line"," vol. 14, no. 2, pp. 243-262, April 2005.

[5] B. F. Nattrass and M. Altomare, The Natural Step for Business: Wealth, Ecology and the Evolutionary Corporation, Gabriola Island, BC: New Society Publishers, 1999.

[6] "The Natural Step," [Online]. Available: http://www.naturalstep.org/en/faq#systems-approach. [Accessed 15 December 2011].

[7] "The Natural Step," [Online]. Available: http://www.naturalstep.org/en/current_projects_all. [Accessed 15 December 2011].

[8] M. Wackernagel and W. E. Rees, Ecological Footprint: Reducing Human Impact on the Earth, Gabriola Island,BC: New Society Publishers, 1996.

[9] T. E. Graedel and R. J. Klee, "Getting serious about sustainability," vol. 36, pp. 523-529, 2002.

[10] "The Top Ten Greenhouse gases," [Online]. Available: http://www.popsci.com/environment/gallery/2009-03/top-ten-greenhouse-gases?image=0. [Accessed 17 Decemeber 2011].

[11] R. Pachauri and A. Reisinger, "Climate Change 2007: Synthesis Report.Contribution of Working Groups I,II and III to the Fourth Assesment Report of the Intergovernmental Panel on Climate Change," IPCC, Geneva, Switerland.

[12] "Parties and Observers," [Online]. Available: http://unfccc.int/parties_and_observers/items/2704.php. [Accessed 15 December 2011].

[13] M. W. Toffel and S. Van Sice, *Carbon Footprints: Methods and Calculations,* Boston: Harvard Business School Publising, 2011.

[14] D. J. Nightingale and D. H. Rhodes, *ESD.38J-Enterprise Architecting Class Lecture Notes,* Spring

2011.

[15] D. J. Nightingale and D. H. Rhodes, "Enterprise Systems Architecting:Emerging Art and Science within Engineering Systems," 2004.

[16] R. Freeman, Strategic Management: A stakeholder perspective, Boston: Pittman, 1984.

[17] T. P. Hughes, Rescuring Prometheus, New York: Vintage Publications, 1998.

[18] D. J. Nightingale and J. H. Mize, "Development of a Lean Enterprise Transformation Maturity Model," *Information of Knowledge Systems Management,* vol. 3, no. 1, 2002.

[19] D. H. Rhodes, "INCOSE Perspectives on Engineering 21st Century Systems," 2002.

[20] "Making those first steps count:An Introduction to Kyoto Protocol," [Online]. Available: http://unfccc.int/essential_background/kyoto_protocol/items/6034.php. [Accessed 15 December 2011].

[21] "Press Release- Transport, Telecommunications and Energy," [Online]. Available: http://www.consilium.europa.eu/ueDocs/cms_Data/docs/pressData/en/trans/92802.pdf. [Accessed 15 December 2011].

[22] "Carbon Counts in the 2007 Renewable Fuel Standard," [Online]. Available: http://www.ucsusa.org/clean_vehicles/solutions/advanced_vehicles_and_fuels/2007-renewable-fuel.html. [Accessed 6 December 2011].

[23] "Supply Chain Engagement," [Online]. Available: http://www.trucost.com/supply-chain-engagement. [Accessed 17 December 2011].

[24] W. R. Blackburn, The Sustainability Handbook: The Complete Management Guide to Achieving Social, Economic and Environmental Responsibility, Environmental Law Institute, 2007, pp. 304-307.

[25] "The Business of Sustainability-Findings and Insights from the First Annual Business of Sustainability Survey and the Global Thought Leaders' Research Project," MIT Sloan Management Review, 2009.

[26] "How to Respond When Retailers Demand Sustainability," [Online]. Available: http://www.greenbiz.com/news/2010/03/31/how-to-respond-when-retailers-demand-sustainability. [Accessed 19 December 2011].

[27] "Greenhouse gas cost abatement curves," [Online]. Available: http://www.mckinsey.com/Client_Service/Sustainability/Latest_thinking/Costcurves. [Accessed 19 December 2011].

[28] R. C. Anderson, Mid-Course Correction: Toward a Sustainable Enterprise: The Interface Model,

Chelsea Green Publishing Company, 1998.

[29] "The Endless Possibilities of a Sustainable Business," [Online]. Available: http://interfaceraise.com/. [Accessed 19 December 2011].

[30] M. Berns, A. Townend, Z. Khayat, B. Balagopal, M. Reeves, M. S. Hopkins and N. Kruschwitz, "Sustainability and Competetive Advantage," vol. Vol.51, no. 1, pp. 19-26, Fall 2009.

[31] H. Iemura, Prius as Dream; Door to the 21st Century by Toyota, Futaba Publishing, 1999, pp. 57-59.

[32] E. M. Reid and M. W. Toffel, "Responding to Public and Private Politics: Corporate Disclosure of Climate Change Strategies," vol. 30, no. 11, pp. 1157-1178, 2009.

[33] H. Baumann and A.-M. Tillman, The hitch hiker's guide to LCA : an orientation in life cycle assessment methodology and application, Lund, Sweden: Studentlitteratur, 2004.

[34] J. Lash and F. Wellington, "Competetive Advantage on a Warming Planet," March 2004.

[35] "The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard, Revised Edition," The World Business Council for Sustainable Development and the World Resources Institute, [Online]. Available: http://www.ghgprotocol.org/files/ghgp/public/ghg-protocol-revised.pdf. [Accessed 21 December 2011].

[36] "General Reporting Protocol," The Climate Registry, May 2008.

[37] "Organizational Carbon Footprints," [Online]. Available: http://www.carbontrust.co.uk/cut-carbon-reduce-costs/calculate/carbon-footprinting/Pages/organisation-carbon-footprint.aspx. [Accessed 21 December 2011].

[38] S. Rothenberg, "Sustainability Through Servicizing," vol. 48, no. 2, p. 83, 2007.

[39] C. Sanne, "Are we chasing our tail in the pursuit of Sustainability?," vol. 4, no. 1, pp. 120-133, 2001.

[40] M. Sawhney, S. Balasubramanian and V. V. Krishnan, "Creating Growth With Services," vol. 45, no. 2, pp. 34-43, 2004.

[41] R. Oliva and R. Kallenberg, "Managing the transition from products to services," *International Journal of Service Industry Management,* vol. 14, no. 2, pp. 160-172, 2003.

[42] F. L. Reinhardt, "Environmental Product Differentiation: Implications for Corporate Strategy," vol. 40, no. 4, pp. 44-73, 1998.

[43] "Carbon Offsets," [Online]. Available: http://www.eci.ox.ac.uk/research/climate/cop07/offsets.php. [Accessed 21 December 2011].

[44] A. Perold, F. L. Reinhardt and M. Hyman, "The Carbon Market," Harvard Business School, 2009.

[45] J. B. R. C. Michael G Luchs, "Trading-off sustainability: Choice and Willingness-to-pay given a trade-off between sustainability and functional performance," Mason School of Business.

[46] D. A. Rondinelli and G. Vastag, "International Environmental Standards and Corporate Policies: An Integrative Framework," *California Management Review,* vol. 39, no. 1, pp. 106-122, 1996.

[47] M. Morsing and M. Schultz, "Corporate social responsibility communication: stakeholder information, response and involvement strategies," vol. 15, no. 4, pp. 323-348, 2006.

[48] Y. Choinard and M. S. Brown, "Going Organic: Converting Patagonia's Cotton Product Line," vol. 1, no. 1, pp. 117-130, 1997.

[49] "Imitation by Competitors," California State University, [Online]. Available: www.csulb.edu/~skukalis/mgmt647/Chapter07Slides.ppt. [Accessed 22 December 2011].

[50] M. Maier and E. Rechtin, The Art of Systems Architecting, CRC Press, 2002.

[51] "Xerox Managed Print Services," [Online]. Available: http://www.consulting.xerox.com/gartners-magic-quadrant/enus.html. [Accessed 4 January 2012].

[52] "HP Managed Enterprise Solution," [Online]. Available: https://h30406.www3.hp.com/campaigns/2010/promo/1-8V1DG/analystscorner.php?analystscorner.php?analystscorner.php&jumpID=ex_r11400_us/en/large/IPG/entpis_ps_g_magicquadrant/MagicQuadrantBMM&k_clickid=AMS|2caf751d-8836-1e09-a3be-000066369774. [Accessed 4 January 2012].

[53] W. B. Rouse, Enterprise Transformation:Understanding and Enabling Fundamental Change, John Wiley & Sons, 2006.

[54] E. Rechtin, Systems Architecting of Organizations- Why Eagles Can't Swim, CRC Press, 1999.

[55] "Wipro Sustainability Report 2009-2010," Wipro, [Online]. Available: http://www.wipro.org/sustainability/pdf-files/Sustainability%20Report%20executive%20Summary%20low%20res.pdf. [Accessed 6 January 2012].

[56] D. H. Rhodes, A. M. Ross and D. J. Nightingale, "Architecting the System of Systems Enterprise:Enabling Constructs and Methods from the Field of Engineering Systems," Vancouver, Canada, 2009.

[57] A. M. Ross and D. H. Rhodes, "Using Natural Value-Centric Time Scales for Conceptualizing System Timelines through Epoch-Era Analysis," Utrecht, The Netherlands, 2008.

[58] A. M. Ross, H. L. McManus, A. Long, M. G. Richards, D. H. Rhodes and D. E. Hastings, "Responsive Systems Comparison Method: Case Study in Assessing Future Designs in the Presence of Change,"

San Diego, CA, 2008.

[59] R. Kaplan and D. Norton, "Linking the Balanced Scorecard to Strategy," vol. 39, no. 1, 1996.

[60] F. Figge, T. Hahn, S. Schaltegger and M. Wager, "The Sustainability Balanced Scorecard – Linking sustainability management to business strategy," vol. 11, 2002.

[61] J. Harold and R. Center, "The MBA's Climate Change Prmier," Stanford Graduate School of Business, 2005.

[62] T. H. Tietenberg, Emissions Trading: Principles and Practice,, Washington DC: Resources for the Future, 2006.