Sustainability Drivers
And Boeing

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University of Idaho Sustainability Center

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INTRODUCTION

Corporate sustainability requires balanced management of economic, environmental, and social resources over both the short- and the long-term. A sustainable corporation thrives in business, nurtures and restores the environment, and cultivates a safe and fair workplace for employees, customers, partners, shareholders, and the global community.

Corporate economic sustainability requires a long-term vision that invests in systemic efficiencies and anticipates emerging financial, environmental, and social scarcities. Corporate environmental sustainability emphasizes natural resource management, conservation, waste minimization, and reuse. Corporate social sustainability requires fiscal, environmental, and human resource management strategies that treat all employees, customers, and partners justly, and takes responsibility for corporate impacts on local, regional and global communities and cultures within which corporations operate.

Traditional corporate culture is beset on all sides by threats to long-term sustainability. Climate change, declining oil production, resource scarcity, and rising energy costs are just a few issues and risks threatening economic and environmental sustainability. Social risks include failed states, massive dislocation and migration of human populations, health crises, poverty, and terrorism. These issues have the potential to increase costs and decrease demand. Collectively, their long-term influence predicts a choke point in traditional corporate growth, be it in 10 or 50 years. Failure to address global risks, uncertainties, inequities, and scarcities is likely to result in a limited and unpredictable corporate future. In contrast, proactive innovation and investment will result in new revenue streams, improved brand image, favorable risk assessments, access to new markets, reduced waste and costs, and an expanded role in shaping global progress.

Long-Term, Cumulative Impacts (Non-Linear Change)

Sustainability generally addresses long-term, cumulative impacts. As traditionally understood, change occurs from gradual, overall patterns of economic, environmental, and social change. Short-term volatility and disruptions occur, but the system of interest continues along a consistent, predictable trajectory. Understanding sustainability requires understanding that incremental impacts add up to cumulative problems that reduce economic, environmental, and social potential and viability.

Such cumulative problems have a high degree of internal complexity caused by synergistic interactions between the individual component problems. This synergy makes the “whole” (the combined impact) larger than the sum of the parts. For this reason, cumulative impacts can lead to “non-linear change,” when shifts are sudden, in an unexpected direction, and conditions do not revert to ‘normal.’ This is the fear with climate change, but non-linear change can also result from failed states or never ending recessions.

Global and Regional Scales

The most severe impacts of both gradual and non-linear shifts are likely to occur at local and regional scales, even though many of the issues are global. Water scarcity, climate change, overpopulation, and loss of biodiversity are all issues which are alarming at global scales in terms of cumulative and long-term impacts. However, the most acute impacts of these issues have generally been local and regional. The overall, cumulative impact is a weakening of economies and a gradual deterioration of possibilities, but complete economic, environmental, and social collapses have tended to be more local or regional in their impacts. The fear is that the scale of these collapses will broaden in geographical scope as well as in intensity.

Scarcity

Resource scarcity in fossil fuels, mineral ores, and water are cumulative and threaten non-linear economic changes, including rapid price increases and limits on manufacturing. Fossil fuel emissions are precipitating non-linear change in the climate by altering global hydrologic and atmospheric cycles. In turn, this affects worldwide water supplies, food supplies, and economic expenditures. Non-linear change is destabilizing and unpredictable.

Proactive Approach

Embracing sustainability requires proactive changes in both corporate philosophy and practice. The goals of corporate sustainability, including resiliency, efficiency, flexibility, and the ability to manage change rather than just react to it, are interdependent factors which strengthen a company in the long-term and help to promote a healthy planet, healthy cultures, and a vibrant global economy.

Sustainability issues permeate business, from supply chains to consumer expectations to fundamental cost considerations. To effectively address these issues and opportunities, a company must understand the complex interactions that influence sustainable business. These relationships are two-fold. We begin with a discussion of how sustainability is driving decisions in corporate boardrooms. We then continue with a more detailed discussion of issues that shape our understanding of true sustainability, including direct and indirect financial, environmental, and social impacts that should be accounted for in corporate decision-making.

SUSTAINABILITY DRIVES BUSINESS

Sustainability's influence on the business world continues to grow. In this first section we define conceptions of sustainable business both generally and as it relates to the airline industry specifically. The frameworks and characterizations in this section shape a vision of how and why sustainable solutions are integrated into the corporate world.

Willard's Sustainability Drivers

Bob Willard (2005) identifies five main categories of drivers that inspire companies to pursue sustainability. These are (not in order of importance) 1) founder's personal passion for doing the right thing, 2) a growing public relations crisis, 3) regulatory pressure, 4) a combination of threats and risks to viability ("a perfect storm of threats"), and 5) a compelling business value. These drivers are combined with 15 drivers identified by a 2002 Government of Canada study of ten companies and a 2003 GlobeScan survey of 201 experts in 40 countries in Table 1,

THREE FIRST-WAVE DRIVERS	TWO EMERGING DRIVERS
1. *Founder's Personal Passion* • Corporate values / "Right thing to do" * 2. *Public Relations Crisis* • Reputation / Brand image* • Relations with stakeholders / Dispute resolution / Issues Management* 3. *Regulatory Pressure* (or threat of it) • Compliance with regulations* • Expedited permitting / Relations with regulators* • Regulations / Enforcement** • Legislated product performance standards** • Legislated reporting** • Voluntary agreements** • ISO 14000**	1. *A Perfect Storm of Threats* • Reduced business risk* • Improved reputation with investors, bond agencies, banks* • Social license to operate or grow* • Changing stakeholder expectations* • Economic instruments** 2. *Compelling Business Value* • Improved access to markets / customers* • Cost savings / Improved bottom line* • Attract and maintain skilled employees* • Increased employee morale and productivity* • Stimulate innovation* • Input to strategic planning* • Corporate role models*
*From 2002 Government of Canada CSR cross-industry survey of ten companies **From 2003 GlobeScan survey of 201 experts in 40 countries	

Table 1 Sustainability Drivers (reproduced from Willard, 2005)

Doing the Right Thing

Many companies have adopted sustainability practices because it is the right thing to do from an ethical, environmental, or social perspective. In some cases, the move towards embracing corporate responsibility measures takes place regardless of the financial analysis of the outcomes because corporate responsibility becomes a central purpose of the business. When 'doing the right thing' is the central motivation of change it usually occurs in privately-owned businesses, and less often in shareholder-owned corporations (Willard, 2005). ‘Doing the right thing’ can still be an important motivator, but is usually one factor in motivating change along with other drivers that include a strong business case for change. For publicly-traded corporations, the motivation to act ethically is usually more effective when it is embedded within a business case that shows that it is also better for the bottom line (Willard, 2005).

Public Relations Crisis

DuPont, Nike, Gap, and Union Carbide are all examples of companies who made increased commitments to sustainability as a result of public relations crises that threatened their reputations. A company’s brand is one of its biggest values. The goodwill accumulated through sustainability practices leads to brand enhancement and helps to reduce the risk of a public relations crisis, or to reduce the impacts on reputation if a crisis occurs. To be effective, companies must go well beyond a communications exercise and actually stop activities that pose a risk to the foundation of a good reputation (Willard, 2005).

Regulatory Pressure

Regulatory compliance is a minimum standard for sustainability and can provide an opportunity to become aware of the issues, usually in operational areas relevant to controlling pollution, disposing of hazardous waste, and ensuring a safe workplace for employees. Regulation alters supply chain cost structures, forces new investment to ensure compliance, and impacts fixed price contracts. For some companies, regulation or the threat of regulation, leads to voluntary measures that move well beyond the scope of the regulations themselves. Regulatory pressure can be a driver of sustainability when companies move beyond compliance to innovations in their practices, often to avoid future regulation through their proactive initiatives. Taking early action may help avoid calls for tougher compulsory regulation (Willard, 2005).

Regulatory risk can influence the products a company makes or the processes it uses to create them. Regulatory risks are compounded by regulatory uncertainty. According to the World Resources Institute, “risk can be considered as a mathematical distribution of potential outcomes around known parameters” (Wellington & Sauer, 2006, p. 3). Meanwhile, uncertainty “involves a lack of information for determining the parameters with which to assess investment risk” (Ibid). Uncertainty in regulatory structure is perhaps the greatest risk of all, as it prevents even responsible companies from effectively predicting and controlling threats to investors, consumers, stockholders, and the financial bottom line. Sustainable management frameworks take a leadership role in shaping future regulations, allowing corporations to minimize exposure to risk and manage future costs.

Perfect Storm of Threats

Risk management is an increasingly important driver of change towards sustainability. In addition to the risks discussed above, Willard (2005) identifies “a perfect storm of threats,” which he describes as emerging market forces that if considered separately, may initially appear irrelevant, but if considered synergistically, can be devastating. These market forces are a combination of the rise of demanding stakeholder groups and a multitude of risks. Demanding stakeholder groups include “Green” consumers, who are concerned about both social and environmental issues, and are a rapidly growing demographic, especially in the younger age groups. Activist shareholders are also on the rise. Of the 862 resolutions filed at Annual General Meetings in 2003 for publically traded US companies, 237 concerned social and environmental issues (Willard, 2005). The number of NGOs active in the world has rapidly increased over the last few decades to number in the millions. As part of the civil society sector, activists and NGOs represent a market force that needs to be engaged as influential stakeholders; failure to do so can result in adversarial relationships that consume both time and resources.

Social and environmental considerations are also an increasingly significant aspect of mainstream investment decision-making. On average, 35% of the information used to justify investment decisions and predict share price is nonfinancial, including many sustainability-related risks or value-driven sustainability opportunities (Willard, 2005). These increasingly influential, sustainability-conscious stakeholders represent a trend towards rising expectations for businesses. Valuing diversity, supporting worthy causes in the community, and going beyond minimum safeguards required by regulation used to be considered leading or enlightened corporate practices, but are often now considered minimum expectations. Companies will be expected to meet increasingly higher social and environmental expectations in the future.

Another factor in Willard's "perfect storm" is litigation risk. For example, a growing body of academic research and case law are demonstrating the links between human fossil fuel use and climate change. As the U.S. federal government continues to avoid regulation, litigation has intensified. The most concrete cases hold fossil fuel-intensive companies and industries liable for environmental and social damages. Specifically, these claims rest on a foundation of product liability and public nuisance (Grossman, 2003). Risks are exacerbated as countries around the world adopt U.S.-style systems of collective redress (Leimbacher et al., 2009). Proactive pursuit of alternative energy sources and life-cycle resource management strategies are essential to combating litigation risk.

The massive short and long-term influences of tort litigation have been witnessed in the tobacco, fiberglass, and asbestos industries in recent decades. These trials and settlements restructured supply chain costs dependent on these products, an effect likely to be replicated in energy and emission-intensive industries like air transportation. Furthermore, the Swiss Reinsurance Company, an industry leader in private reinsurance, "expects that climate change-related liability will develop more quickly than asbestos-related claims and believes the frequency and sustainability of climate change-related claims could become a significant issue within the next couple of years" (Leimbacher et al., 2009, p. 5). Asbestos case law took over a decade of development before its first successful suit. In contrast, climate change litigation emerged in 2004, resulting in a successful claim against a Kansas utility company in 2007 (Ibid). These types of cases increase the likelihood of legislative or administrative regulation, amplify risk and liability exposure for investment by defendant companies, and encourage the industry to accept regulation that will increase costs (Schwartz, 2010).

Compelling Business Value

Willard (2005, p.135) also identifies seven benefits to increasing company sustainability.

1. Easier hiring of top talent by attracting people whose values resonate with company sustainability values and who want to work in that kind of company.
2. Higher retention of top talent since employees caring about a company's environmental and social good works want to stay with it longer.
3. Higher productivity from employees energized by contributing to the success of a firm doing worthwhile work.
4. Reducing expenses in manufacturing through eco-efficiencies, dematerialization, recycling, process redesign, and waste reduction.
5. Reduced expenses at commercial sites through eco-efficiencies in energy and water usage, and increased employee stewardship of consumables.
6. Increased revenue as green consumers are attracted to the company's products, services are expanded, and new markets are opened.
7. Reduced risk and easier financing through risk avoidance, lower insurance premiums, better loan rates, and higher attractiveness to investors.

These values are best realized through a proactive approach that creates competitive advantage. While all businesses can enjoy these benefits, early actors can shape innovation and maximize the benefits of these practices.

While Willard's five principles demonstrate some motivations for corporate sustainability, they are not a guide for action. The following section discusses business frameworks that seek out the emerging markets, strategies, and priorities outlined by Willard.

Sustainability Frameworks

Becoming a corporate leader in sustainability requires moving faster than competitors. Many programs and philosophies address this goal while increasing corporate sustainability.

Eco-Efficiency

One such approach is "eco-efficiency," which develops ways to produce goods and services with fewer resources and less waste and pollution. The goal of eco-efficiency is to deliver "competitively priced goods and services that satisfy human needs and bring quality of life while progressively reducing environmental impacts of goods and resource intensity throughout the entire life-cycle to a level at least in line with the Earth's estimated carrying capacity" (World Business Council for Sustainable Development (WBCSD), 2000). Eco-efficiency requires incremental efficiency improvements in existing practices as well as an emphasis on innovation. Eco-efficiency considers the entire life-cycle of a product, both upstream and downstream of production, and is not limited to areas within a company's operational boundaries.

The goal is to achieve more value from lower inputs of materials and energy, with reduced emissions and waste. All aspects of a company, from production to administration, marketing, product development, and distribution are examined. According to the WBCSD (2000), eco-efficiency has three objectives:

> 1) reduce the consumption of resources: this includes minimizing the use of energy, materials, water and land, enhancing recyclability and product durability, and closing material loops;
>
> 2) reduce the impact on nature: this includes minimizing air emissions, water discharges, waste disposal and the dispersion of toxic substances, as well as fostering the sustainable use of renewable resources;
>
> 3) increase product or service value: this means providing more benefits to customers through product functionality, flexibility and modularity, providing additional services and focusing on selling the functional needs that customers actually want. This raises the possibility of the customer receiving the same functional need with fewer materials and less resources.

Many companies using this approach also have a fourth objective, which is to implement an Environmental or Sustainability Management System. Boeing's efforts to meet ISO 14001 standards are consistent with this fourth objective.

Eco-efficiency focuses on four main areas of opportunity. First, companies redesign their operations to reduce consumption, pollution, and risk while simultaneously reducing costs. Second, companies collaborate with other industries or partners to find value-added uses for their waste streams; one corporation's waste stream becomes another company's feedstock for a production line. Third, companies redesign their products to reduce resources used, waste generated, and other impacts. And fourth, some companies find ways to re-think their markets and re-shape demand and supply completely, finding ways to meet customer needs in ways that are not as material and energy intensive (WBCSD, 2000).

Cradle to Cradle

Another model of achieving corporate sustainability is presented in *Cradle to Cradle*, where McDonough and Braungart (2002) argue for modeling human industry on nature's processes. They envision production processes as being composed of two metabolic systems—biological and technical. Products composed of biodegradable materials become food for biological cycles and inorganic materials stay in closed-loop technical cycles, where they continuously circulate as valuable materials for industry. The two loops need to be carefully separated to avoid cross-contamination.

This view of sustainable production redefines all waste as feedstock for further processes, either biological or technical. In order to eliminate waste, products have to be designed from inception to participate in the larger metabolic processes of biological and technical material flows. The largest problem with landfills is not so much the space or cost considerations, but rather that all discarded materials become mixed and contaminated. This leads to a loss of resources for human use, and ultimately drives up prices as a result of increasing resource scarcity. McDonough and Braungart (2002) criticize eco-efficiency for only considering these issues as an afterthought. They suggest that most businesses still focus on economic health as a singular indicator of success, while environmental and social goals are secondary or external to company purpose. A cradle to cradle approach, on the other hand, integrates environment, economy, and social equity into the industrial design process. This is the attitude that will drive innovation.

Synthesis

The emphasis on design at the center of McDonough and Braungart's (2002) approach to sustainability has promise, and a number of companies have implemented the process successfully. Still, for many industries basic infrastructure changes will be necessary to maximize the benefits of competitive advantage, reduced waste and new revenue streams this approach creates.

L. Hunter Lovins (2008) argues that eco-efficiency as implemented at the level of individual businesses is an important transition towards system-wide sustainability. Eco-efficiency tailored to existing processes "buys the critical time necessary to solve such daunting problems as climate change and to develop and implement production methods that meet humanity's needs in ways that do not cause more problems." Lovins (2008) highlights initiatives that focus on 4, 10, and 20-fold increases in production and distribution efficiency that are proving to be feasible and achievable in the marketplace.

This tension between improving the efficiency of existing systems and completely redesigning processes from the start exists in discussions about other methods and goals of sustainability. For example, David Owen (2009) criticizes the green building movement for focusing on buildings rather than overall urban design. He makes a strong case that some of our best examples of green facilities have net negative resource impacts because they do not account for their impacts on external social and environmental systems, such as ground transportation. Ultimately, to have meaningful zero-impact facilities, we will need to redesign our urban and regional infrastructure. To take this approach to the level of idealism represented by McDonough and Braungart (2002), each corporate facility should have a positive impact on the environment and society. In addition to providing economic benefits at the corporate, local, and regional level, helping to drive change towards economic and environmental sustainability at a macroeconomic level is fundamental.

Moving towards sustainability will require a transition that integrates these different approaches. Redesigning regional infrastructure, or entire sector-wide production processes, is in most cases a long-term process that ignores many important improvements that can be made in shorter time frames. At the same time, increases in efficiency will only reach their full potential benefits if larger system-wide changes occur. To truly be a leader in sustainability, Boeing needs to develop sustainable practices at both scales simultaneously.

Boeing's success in ensuring that all facilities are ISO 14001 compliant places it in a strong position to move forward on environmental sustainability. In addition, Boeing's expressed interest in working with its suppliers to share best practices in sustainability is a step in the right direction. Fixed, quantifiable goals for improvements in this area should be set. Boeing's use of the Global Reporting Initiative (GRI) makes sense and brings Boeing into line with other corporate leaders and should be pursued. Organizations already using the GRI include 3M, Air France, Apple Corporation, Alcoa, Sony, Royal Dutch Shell, Proctor and Gamble, and Korean Airlines (GRI 2010).

Sustainability and the Commercial and Military Air Transport Industries

Drivers of corporate economic sustainability include both demand-side and supply-side pressures. Demand-side pressures, particularly in the U.S., include government policy, global business trends, and consumer preferences. Supply-side pressures include future energy costs, resource scarcity, and the ability to respond to potential future pressures on product pricing.

As an American company with a global market in a struggling, resource and energy-intensive industry, one could argue that Boeing faces one of the most complex and uncertain business environments in the world. This section draws out three drivers specific to Boeing's U.S. operations: changes in the commercial airline industry, the U.S. Military's commitment to sustainability, and the certainty of eventual regulatory change. This effort to identify specific hazards to Boeing's operations is extended through numerous examples in part two of this report, "Issues Drive Sustainability."

Sustainability Drives the Commercial Airline Industry

Economic Crises

In 2000, the air-transportation sector was growing more rapidly than any other transportation sector. Between 1970 and 1990 air passenger transit grew 260%, while air cargo increased 220% (Dempsey, 1999-2000). It was commonly assumed that global air transportation would double in 10-15 years, with some estimates projecting a 500% increase over 50 years (ibid). The events of September 11, 2001 fundamentally changed public perception of air-travel safety and security. Despite major financial intervention from the Federal Government shortly after the attacks, the airline industry is still dealing with the economic repercussions of a new era of air-borne terrorism. In the last two years, this precarious economic position has been exacerbated by the global economic crisis, as investors and consumers reconsider their financial choices.

In March 2009, the International Air Transport Association (IATA) announced a $62 billion (12%) loss in revenue for 2009. This was greater than a 6% drop in 2002, following the 9/11 attacks. The IATA forecast accounted for a 5.7% and a 13% drop in passenger traffic and air cargo, respectively. As of 2009, the Asian market was particularly vulnerable. According to Giovanni Bisignani of the IATA, "the industry is entering into serious intensive-care mode" (Pilling, 2010). Based on these problems and uncertainties, a highly non-linear growth trend seems likely for the aviation sector. Fundamental elements of sustainability, including adaptability, innovation, and long-term planning, will become increasingly essential components of the global aviation industry.

The Rise of Green Consumerism

After highway transportation, the airline sector is the largest consumer of petroleum for fuel. The per person, per kilometer CO_2 emissions of aviation are 4-8 times greater than that of automobile transportation, more than 10 times that of travel by bus, and a remarkable 22 times greater than that of electric-powered trains (Hindley, 1996). Air-freight contributions of CO_2 are 20 times greater than emissions from medium-size truck freight, and up to 240 times greater than emissions from railway freight (OECD, 1996).

With future increases in oil prices, airlines have a direct economic incentive to reduce their fuel consumption. At the same time, public awareness of the climate impacts of fossil fuel use is growing rapidly. These factors are forcing airline companies to maximize their fuel efficiency, both to reduce the cost of their operations and to provide conscientious consumers with services that limit climate impacts. Airlines face a dual challenge. They must survive the present economic turmoil while remaining competitive in a market demanding increasingly “green” services. Over time, decommissioned fleets will have to be replaced with maximum fuel-efficiency aircraft, both due to the airlines’ need for reduced fuel consumption to cut costs, and to provide competitive services with reduced environmental impacts to the public, especially in Western Europe and North America.

The market forces resulting from a growing demand for transportation with low environmental impact are quickly gaining leverage. According to Gil Friend, Founder and CEO of Natural Logic, there is an emerging “creative consumer sector” that now accounts for as much as 25% of US consumers, particularly among the middle class (2009). This “creative consumer sector” has shown a proclivity for environmental products and services. Much like air travel consumers, this emerging sector is primarily upper-middle class. Friend (2009) also highlights EU regulations and protocols as a major driver of consumer demand in sustainability. These trends are changing public perceptions of transportation itself. Where time, convenience, and price alone used to dictate transportation choices, climate impacts are now entering the decision-making process. Electronic communication is also becoming an important alternative to transportation-based communication and meetings for reasons of cost, convenience and ecological impact.

These switches in transportation-mode and communication preferences will become even more pronounced if a global airline industry in “serious intensive-care mode” is unable to re-create itself as a “green” alternative, providing services with fuel-efficient, state-of-the-art fleets.

Commercial Airlines and Sustainability

Airlines are responding in various ways to a number of emerging drivers of environmental policy. These drivers are located on a continuum between external and internal drivers, where the internal drivers are issues specific to a given company. External drivers are outside the direct influence of the given company. Internal drivers are evolving under the influence of external drivers, and therefore cannot be completely isolated (Lynes & Dredge, 2006). At the global forefront of sustainable practices we find companies like KLM Royal Dutch Airlines and Scandinavian Airlines (SAS), both of which have acted proactively to avoid regulation and to gain business advantages through environmental management.

As airline companies endeavor to enhance social and environmental responsibility, they must integrate influences, strategies, and goals from four different systems: market systems, political/institutional systems, scientific systems, and social systems. Each of these systems provides their own incentives and challenges for pursuing corporate social and environmental responsibility (Lynes & Andrachuk, 2008). Taking a leadership role in driving these systems will make companies more adaptive to unpredictable future trends and open new system innovations to enhance reputation, responsibility, and the financial bottom-line.

Case Studies: SAS and KLM

Lynes & Dredge (2006) studied the drivers affecting airline sustainability, illustrated by a case study of SAS. They found that airlines, in general, recognized the necessity of increased eco-efficiency to reduce financial loss. Fear of regulation and pressure from "environmentally conscientious" employees (especially a few "environmental visionaries" and younger employees) were found to be major internal drivers. Since 1995, SAS has repeatedly stated that their motivation for continuous reduction of environmental impacts is a mix of ethical principles, economic efficiency, company-image improvement, passenger interest, insurance and bank-related liability concerns, and potential competitive advantages.

Even in the wake of 9/11, SAS kept environmental performance high on the agenda. Strategic cost-saving measures in 2001, focused on efficiency, resulted in the single greatest increase of the company's environmental index. Increasing environmental-performance demands of present and prospective corporate customers is a major external driver at SAS. Pressure from passengers, however, was not identified as a major driver. The authors concluded that this was due to Scandinavian customers expecting a high level of environmental commitment from large corporations like SAS, and perceiving SAS as doing "what they can" to mitigate their environmental footprint. SAS's long-standing commitment to environmental practices has helped them earn this implicit trust from the highly educated and environmentally-demanding public in Scandinavia.

In the case of KLM Royal Dutch Airlines, the motivation for proactive adaptation has been to retain the airline's and the country's central role in the EU market. The Amsterdam Airport, Schiphol, is a hub for international transportation and commerce. In recognition of the airline industry's importance for the national economy, the Dutch approach to sustainability has been highly integrated, involving close collaboration with numerous stakeholders. These include the Royal Netherlands Airforce, the Delft University of Technology, and various industry organizations. KLM seeks to gain a competitive advantage by implementing stringent EU guidelines at an early stage (van Leeuwen, 2009). KLM is fully ISO 14001 certified, and claims to be 25% more fuel efficient than comparable European airlines (KLM, 2009). The company is also involved in research to develop biomass-based aviation fuel. KLM has formed an alliance with Air France to form strategies to reduce airline-industry carbon emissions through the Aviation Global Deal (AGD) Group (ibid). These innovative efforts establish KLM as an industry leader and provide new opportunities for growth.

For airline companies, an inevitable conflict exists between immediate economic survival and costly long-term improvements to reduce environmental impacts. This conflict is a serious obstacle to implementing potentially costly changes, such as retrofitting fleets to improve fuel economy. However, as fuel prices increase and new regulations take effect, airline companies will be forced to reduce fuel consumption more drastically and more immediately, regardless of short-term cost or efficiency.

The International Air Transport Association (IATA)

The International Air Transport Association (IATA) represents the global airline industry (230 member airlines and 93% of scheduled international traffic), which accounts for 2-3% of worldwide greenhouse gas emissions. In an effort to build competitive advantage in a market recognizing the need for reduced carbon footprints, IATA brought the industry's "self-imposed" reduction goals to the 2009 United Nations Climate Change Conference in Copenhagen. According to Giovanni Bisignani, IATA's Director General and CEO, the airline industry was the "only global industry coming to Copenhagen with a strong track record and a commitment to cut… emissions in half by 2050," which placed the industry "ahead of its regulators in its approach to climate change" (IATA, 2009).

According to the IATA, the emissions of the total industry are expected to decline by 7% during 2009 alone – 5% due to economic recession, and 2% from the industry's "Four-Pillar Strategy" (IATA, 2009):

1. Investment in new technology
2. Improved traffic management and flying
    a. Smarter traffic control
    b. More efficient landing strategies
    c. Shortening routes
    d. Implementing fuel-management best practices
3. Building better infrastructure
4. Improving economic efficiency

The airline business is inherently non-local and transnational. For this reason, IATA has taken a "Global Sectoral Approach" to carbon-emission reductions as outlined on their website: (http://www.iata.org/whatwedo/environment/climate_change.htm). This approach is particularly relevant to Boeing as IATA seeks to standardize industry regulations and practices, increasing the likelihood that more progressive global standards will put pressure on emerging aviation markets and American companies alike.

The Global Sectoral Approach

The goals of IATA's Global Sectoral Approach are:

1. To make combined aviation emissions fully accounted for as one global industrial sector.
2. To coordinate economic measures globally so that aviation "pays only once" for its emissions.
3. To provide airlines with access to global carbon markets.

According to IATA, this approach will enable national airlines to offset their carbon footprints while eliminating unfair competition in local markets at various stages of development. This is a necessary step, as numerous airlines are controlled by federal interests, increasing the incentives for localized policies that economically favor a particular airline. IATA expects this approach to "level the playing field" and make globally sustainable aviation economically feasible.

The carbon goals that IATA presented at the 2009 United Nations Climate Change Conference in Copenhagen are (IATA, 2009):

1. to improve fuel efficiency by an average of 1.5% per year to 2020,
2. to stabilize carbon emissions from 2020 with carbon-neutral growth,

3. to achieve a 50% net reduction in carbon emissions by 2050 compared to 2005.

The Kyoto protocol gave the International Civil Aviation Organization (ICAO), the specialized UN agency for aviation, responsibility for aviation's international emissions. IATA and its members are working with governments under ICAO's oversight to achieve the carbon goals of the industry.

During 2010, ICAO and its contracting states will evaluate if they can set "more ambitious goals" after considering the industry's present collective commitments and the "special needs of developing nations." Other ICAO 2010 objectives are to develop a "framework for economic measures" (i.e., improve the economic efficiency of airlines), and encourage the development and use of sustainable biofuels for aviation.

The proactive carbon-reduction approach of the airline industry is commendable. IATA's Four-Pillar Strategy is already yielding tangible results. ICAO is an organization with a 65-year track record of successfully working with industry to create global aviation standards. ICAO standards for safety, security, efficiency, and environmental responsibility have already been effectively implemented by governments around the world (IATA, 2009). These previous successes provide evidence that the industry has the practical experience of effective collaboration to implement changes as one global industrial sector.

Challenges to the Global Sectoral Approach

The 2009 Copenhagen climate summit failed to deliver a new global climate agreement, making it difficult to predict how carbon trading will develop without a large-scale cap-and-trade agreement in place. For this reason, the future of effective global carbon-credit trade appears highly uncertain at this time. The aviation industry anticipates its entry into the Emissions Trading System (ETS) in 2012 (KLM, 2009). Without an effective global trading market, however, IATA's Global Sectoral Approach to reduce CO_2 emission cannot be realized. Nevertheless, global aviation is a large transportation sector with the leverage to support the development of a functional global carbon-trading system. It is possible that IATA will seek to define the "rules of the game" at an early stage for the industry's own benefit.

It is also uncertain that the IATA's Four-Pillar Strategy will lower CO_2 emissions beyond the "low-hanging fruit" of increased fuel efficiency. The advocated strategies do not seem to be sufficient to reach IATA's carbon goals for 2050. The global airline industry is overly positive when it comes to reducing its CO_2 emissions by the development of "next generation biofuels" (IATA, 2009). Biofuels are in the early stages of research and development and much uncertainty remains as to their effectiveness as a central strategy for reducing emissions.

Another complicating factor is the conflict between the immediate economic viability of the airline industry and its costly long-term investments to reduce environmental impacts. Lynes & Dredge (2006) recognize that implementation of voluntary sustainability goals will be in conflict with the economic competitiveness of some individual airline companies. These companies will likely seek ways to compromise on environmental performance for economic reasons.

However, the synergistic effects of rising fuel prices and increasing public demand for “green” transportation will eventually force airline companies to reduce fuel consumption, though it is difficult to predict how rapidly these changes will occur. When they do occur, however, companies that have not addressed sustainable fuel sources will be forced into more drastic and costly action.

Sustainability and the U.S. Military

A significant amount of demand-side pressure for Boeing to move towards a sustainable corporate model comes from the U.S. government, particularly from the U.S. military. The U.S. Army published its first annual Sustainability Report, Sustainability Report 2007: Sustain the Mission, Secure the Future, in September of 2008 (U.S. Army, 2008). This report specifically states that “the Army Strategy for the Environment transitions the Army’s compliance-based environmental program to a mission-oriented approach based on the principles of sustainability” (Ibid, p. 1).

The Army is committed to integrating sustainability into its day-to-day operations and decision making (U.S. Army, 2004). This stance extends to all branches of the military, in large part due to the Department of Defense’s strict interpretations of federal policy, including the Energy Independence and Security Act, the Energy Policy Act of 2005, and the National Environmental Policy Act (Department of Defense, 2004).

The U.S. Military is not satisfied with meeting basic requirements; they endeavor to drive innovation. Numerous policies and instructions provide a foundation for sustainable military planning strategies, including Department of Defense publications on Sustainable Development (JSPP, 2004), Energy Management (Department of Defense, 2009), Resource Conservation (Department of Defense, 1996), and Green Procurement (Office of the Deputy Under Secretary of Defense, 2008).

Because the military’s mission is to serve and protect the United States in perpetuity, they consider themselves duty-bound to ensure long-term viability. The U.S. Military is also a major part of Boeing’s Defense, Space and Security (BDS) division’s corporate economic sustainability. As a result, an equally robust commitment to sustainability will allow Boeing to achieve the same standard of longevity. According to Boeing’s 2008 Annual Report, 46% of total revenue is derived from U.S. government contracts. That same report minces no words in describing the military’s role in Boeing’s corporate model: “because U.S. DoD spending was about half of worldwide defense spending and represented approximately 80% of BDS revenue in 2008, the trends and drivers associated with the U.S. DoD budget are critical” (Boeing, 2008).

Regulatory Changes

It is impossible to predict when and how the U.S. will regulate greenhouse gas (GHG) emissions. Even if cap-and-trade legislation is passed in the U.S., as the growing body of knowledge causes government and private regulators to reevaluate the risks of climate change, regulatory uncertainty will remain. Regulation will always lag behind innovation (Friend, 2009), but companies that maximize innovation will likewise maximize competitive advantage, corporate versatility, and influence over the uncertain development of climate change regulation (Willard, 2005). Companies in the extractive, transportation, and manufacturing industries are particularly vulnerable as they are the largest emitters of GHGs (Wilhelm, 2009).

While it is uncertain what form regulation will take in the United States, standards have been implemented in a number of countries. Carbon taxes have already been passed in Quebec, Canada, and Sweden. Cap-and-trade systems are in place in the European Union (Emissions Trading Scheme), and Australia, Japan, and Russia are currently developing similar systems (Wellington & Sauer, 2006). In addition, Clean Development Mechanisms (CDMs), which provide incentives for developing countries to reduce emissions, are growing as well, with China leading the way (Wilhelm, 2009). Any business that targets a global market will need to adapt to this global regulatory climate. Failure to do so poses a serious threat to long-term profitability, stability, and even survival.

In the United States, local and regional initiatives are driving regulatory policy in the absence of federal leadership. Boulder, Colorado has an established carbon tax structure. California has advanced its own vehicle emissions standards (Lash & Wellington, 2007) and passed the first mandatory emissions cap in the U.S. (Friend, 2009). Three regional cap and trade programs, the Regional Greenhouse Gas Initiative, the Midwestern Regional GHG Reduction Accord, and the Western Climate Initiative, include 23 participating U.S. states. The Chicago Climate Exchange features numerous public and private partners in a similar, continental carbon market. Twenty-six states have established renewable portfolio standards, requiring the development of alternative energy sources (Wilhelm, 2009). The fragmented nature of these piecemeal regulations and initiatives has actually led many corporate leaders, including more than 40 Fortune 500 companies, to call for “rapid enactment of mandatory, economy-wide regulatory programs” (Lash & Wellington, 2007, p.6).

Private regulations from the insurance and investment sectors are also driving corporate conceptions of risk. The Carbon Disclosure Project, for example, representing $31 trillion in investment assets, has begun requesting information on “climate-risk positioning” from multinational corporations. Other coalitions are filing shareholder resolutions that demand further disclosure of climate risks (Lash & Wellington, 2007). Insurance and reinsurance companies, including AIG, Allstate, Swiss Re, and Munich Re, are also integrating climate change into requirements and calculations for insurance coverage. Swiss Re in particular, with $117 billion in assets, has named sustainability as one of their four core values (Swiss Re, 2010). Increased pressure from the insurance sector is both cause and effect of a recent U.S. Securities and Exchange Commission vote to require companies to disclose climate change risks (Hughes, 2010). A business model built on sustainable principles will reduce these risks, thereby reducing insurance costs and increasing investment opportunities. Proactive innovation could even enhance investor interest and position companies for robust expansion into new markets and research opportunities.

If the U.S. government, the U.S military, the commercial airline industry and insurance companies move toward sustainability as a driver of economic modeling, their decisions will have both lateral effects (motivating changes in other markets) and vertical effects (changing the global supply-chain) on all manufacturers. Boeing must anticipate these developments and stay on the cutting edge of corporate innovation. Doing so will minimize risk, enhance investment opportunities, build consumer confidence and brand image, and mitigate cost uncertainty.

Willard, the WBCSD, McDonough, Braungart, Friend, Lovins and numerous other scholars have laid the foundation for a business case for sustainability. The next step is for thoughtful corporations to consider long-term impacts and adapt sustainable business models to their unique circumstances. This proactive innovation and investment will drive corporate growth for decades to come, building competitive advantage for first actors. The following section provides additional context on factors that fundamentally influence how aggressive and creative corporations must be in their pursuit of sustainability.

ISSUES DRIVE SUSTAINABILITY

Clearly, sustainability is a significant driver of innovation for business generally, within the airline industry, and for Boeing in particular. However, these corporate conceptions are a small part of a much larger, global trend. While sustainability drives business, a variety of political, environmental, financial, and social issues are driving conceptions and understandings of what is truly sustainable. Too often, we assume that sustainability is a panacea for all the world's problems: a static ideal that we can achieve through checklists and good intentions. What this section demonstrates is that we still struggle to fully understand how far innovation must go.

Energy Costs

The problems associated with world dependence on fossil fuels are well understood. Little serious debate exists that non-renewable energy sources will become increasingly scarce and expensive over the long-term. Although significant short-term fluctuations in pricing have and do occur, long-term projections are that energy prices will steadily increase as supplies diminish and demand increases. This will have a cascading effect on all related goods and services.

Within the U.S. Department of Energy, the Energy Information Administration (EIA) publishes the most widely recognized energy-price forecasts originating in the United States. According to the EIA, prices for all sources of energy throughout the U.S. will increase moderately over the next 20 years, regardless of short-term or local fluctuations (see Appendix A). The EIA's long-term energy price forecasts are based on "business-as-usual trend estimates" (2009, p. 57). In other words, EIA's forecasted energy prices are based on a steady-state cultural scenario using current legislative frameworks with no significant changes assumed in the forecast. The EIA's projections do not account for factors that impact energy prices, such as government-policy initiatives (e.g., responses to climate change), macroeconomic growth, political crises, technological changes, and the relative prices of other energy sources such as coal or natural gas. The EIA's "business-as-usual" approach limits the accuracy and usefulness of the EIA's energy price forecasts, in part because of the inherent unpredictability of the impact associated with many issues. For example, the EIA's margin of error when comparing its forecasted oil prices with the actual price of oil has, on average, ranged from 52.9 to 65.5 percent (EIA, 2008).

The degree of uncertainty in the EIA's future energy price projections becomes increasingly apparent when compared with other oil price projections (see Table 2). Market volatility and differing assumptions about future economic conditions are reflected in the variability of the projections. For example, Energy Venture Analysis, Inc. (EVA) predicts oil prices to rise steadily over the next twenty years while another group, the Institute for Energy Economics and the Rational Use of Energy (IER) at the University of Stuttgart, predicts oil prices to stabilize around $70 dollars a barrel. The other oil price projections in Table 2 were derived from Deutsche Bank (DB), IHS Global Insight (IHSGI), International Energy Agency (IEA), and Strategic Energy and Economic Research, Inc. (SEER).

Sources	Years				
	2010	2015	2020	2025	2030
EIA 2008 (reference case)	75.97	61.41	61.26	66.17	72.29
EIA 2008 (high price case)	81.08	92.77	104.74	112.1	121.75
EIA 2009 (reference case)	80.16	110.49	115.45	121.94	130.43
DB	47.43	72.2	66.09	68.27	70.31
IHSGI	101.99	97.6	75.18	71.33	68.14
IEA	100	100	110	116	122
IER	65.24	67.03	70.21	72.37	74.61
EVA	57.09	74.61	95.33	105.25	116.21
SEER	54.82	98.4	89.88	82.1	75

Table 2 Projections of World Oil Prices, 2010-2030 (2007 dollars per barrel) (Adapted from the EIA's (2009) Annual Energy Outlook).

Due to the inherent uncertainty and variability in future energy price forecasts, we must take a more in-depth look at energy economics to adequately explore future energy prices. As oil provides roughly 40 percent of the total commercial energy consumed and about 98 percent of mobile fuel in the United States, we will use it as our primary example in our discussion of future energy prices.

Future Oil Prices

For the last 30 years, the consumers of oil have enjoyed an unprecedented supply of cheap petroleum. The world's oil producers have provided the world with an enormous surplus creating a buffer in global oil reserves (Hopkins, 2009). This buffer allowed supply to meet demand and helped to maintain a relative balance in the marketplace. However, this balance will soon be lost as supply continues to lose pace with growing demand.

A multitude of factors influence oil prices, including the value of the U.S. dollar, financial speculation, government subsidies, oil supply, and policy issues (Pirog, 2008). However, one of the most significant factors influencing the price of oil is demand. This was made apparent in 2008 when world oil prices reached record highs as a result of heightened demand. The oil industry is characterized by time lags and an inability to easily expand output (Pirog, 2008). Any increase in demand that exceeds current production must be countered by reducing excess capacity. When excess capacity falls, markets assume future excess capacity will be less able to accommodate future supply disruptions and prices increase.

This is precisely what caused prices to reach record highs in 2008 (see Table 3). The demand increases in 2004 of 3.5% (over 2.8 million barrels a day (b/d)) reduced spare world capacity and tightened the balance between oil supply and demand (Pigor, 2008).

Year	Demand	Growth %	Year	Demand	Growth %
1997	73,598	5.8	2003	79,96	1.9
1998	73,939	0.05	2004	82,111	3.5
1999	75,573	2.2	2005	83,317	1.5
2000	76,340	1	2006	84,23	1.1
2001	76,904	0.07	2007	85,220	1.2
2002	77,829	1.2			

Table 3 World Oil Demand 1997-2007 (thousand barrels per day)*

* According to the BP Statistical Review of World Energy, growth is the percentage change in a year over the previous year (as cited in Pirog, 2008).

Although world growth fell the following year to 1.5%, demand still exceeded supply and required a further expansion of 1.2 million b/d. Again, world production could not expand quickly enough to meet this new demand. As a result, further reductions of capacity occurred, the oil market got even tighter, and prices continued to increase. That was, of course, until the oil market crashed as a result of the world financial crisis. However, the majority of long-term projections predict demand to continue its steady rise. The International Energy Agency (IEA) projects demand for oil to continue to grow by 1% per year up to 2030 (i.e. from 85 million barrels per day in 2008 to 105M b/d in 2030) (IEA, 2009).

The two main forces driving these increases in the world's demand for oil are (1) increases in the world's per capita Gross Domestic Product (GDP) and (2) population growth (Hopkins, 2009). This verifies what many people already suspect: people consume energy, wealthier people consume more energy, and that the developing world is becoming wealthier.

According to the United Nations (U.N.), the world population is currently estimated at 6.7 billion and is expected to grow to 9.2 billion by 2050 (United Nations Department of Economic and Social Affairs Population, 2008). Similarly, the world GDP, driven by both population growth and increased personal wealth, is expected to continue to increase (Organization of the Petroleum Producing Companies [OPEC], 2009).

Future population growth and growth in per capita GDP will be especially prevalent for the world's two most populous countries, China and India (OPEC, 2009). Both countries have recently seen dramatic increases in the size of the middle class, along with tremendous economic booms – both of which are expected to continue. From 1980 to 2005, China's GDP growth averaged nearly 10% annually (International Energy Agency [IEA], 2007). Similarly, economic growth in India has steadily risen. In the 1980s and 1990s, India's GDP grew by almost 6% annually (Kjarstad & Johnsson, 2009). That number jumped to 8% in 2004 and to nearly 10% in 2006.

The transportation sector will account for 97% of the increases in oil consumption up to 2030 (EIA, 2009). Growth in the transportation sector will be most prevalent in developing regions such as Asia, the Middle East, and Africa. Car sales alone will strongly affect demand; in the BRIC countries (Brazil, Russia, India, and China), car sales are booming. In 2007 alone, car sales rose by almost 60% in Russia, 30% in Brazil, and more than 20% in China (Kjarstad & Johnsson, 2009).

Increased demand for oil has and will increase the future price of oil. However, sustained higher oil prices also have the potential to alter expected increases in future oil demand. This is especially true in the case of climate change where a cap-and-trade system, carbon taxes, or some other form of market or regulatory mechanism will increase energy costs and reduce demand.

The speed at which alternative energy sources are developed and implemented will also impact the oil market by moderating the trend toward higher prices (Tsoskounoglou, 2008). However, since most renewable energy technologies in development are related to the production of electricity rather than liquid fuels, the impact of these technologies on the transportation sector will be limited (Almeida & Silva, 2009).

Oil Scarcity

Unfortunately, increasing oil production is becoming more difficult and expensive. This is the result of a number of confounding issues, but comes down to one problem. We are running out of oil that is easy to access, extract, and process.

For one, rates of decline for existing oil fields are on an upward trend. According to Jackson & Eastwood, the average rate of decline ranges from 2-4 percent in big onshore fields and up to 18 percent in some deep-water fields (as cited in Almeida & Silva, 2009). This implies that approximately 3 mb/d of new capacity must be added each year in order to maintain current levels of production, or the equivalent of a new Saudi Arabia coming into production every three years (IEA, 2009). This depletion problem is exacerbated as the biggest oil fields in the world (such as Cantarell and Burgan) reach peak production and the number of rapidly depleting deep-water fields increase (Almeida & Silva, 2009). More than two-thirds of current crude oil production capacity may need to be replaced by 2030 to prevent production from falling.

New oil-field discoveries have also decreased in number, further exacerbating the supply problem. The lowest discovery rates since the 1940s were in 2004 and 2005 (Greene et al., 2004). In 1940, the average size of fields found over the previous five years was 1.5 billion barrels. By 1960 it had fallen to 300 million barrels, and by 2004 it was a meager 45 million barrels. These discovery rates continue to fall (Strahan, 2007). In addition, the discoveries that have been made are in geographically and politically challenging environments. Since 1999 the majority of new discoveries (65%) have been under the ocean in waters more that 200 meters deep (Cooke, 2004). Extracting oil under these conditions is extremely difficult, ecologically risky, and expensive.

Similarly, a recent study suggests that the proportion of conflict zones overlapping oil-producing areas has increased from roughly 20% to 40% since 1989 (Le Billon & Cervantes, 2009). Moreover, out of seventy-five major events identified by the EIA affecting world oil prices between 1970 and 2006, fifteen were conflicts followed by price increases (EIA, 2007).

Although the idea of a peak in world oil production (i.e., peak oil) was disputed when first presented, the concept is now well accepted (Almeida & Silvia, 2009). The timing of the peak, however, is still open for debate (see Table 4). All but two projections state that global oil production will pass its peak sometime this century, with 80% predicting peak by 2020. Once past the peak, production will flatten or begin to decline. Part of the cause of this debate in peak oil projections is the limited and sometimes contradictory data available concerning reserve amounts as well as production and depletion rates. As a result, peak oil projections vary widely. This uncertainty about the date of peak oil unfortunately diminishes the sense of urgency that the problem requires.

Date of Forecast	Source	Peak Oil Date	Reference
2000	Bartlett	2004-2014	Bartlett (2000)
2000	EIA	2021-2112	Wood and Long (2000)
2000	IEA	Beyond 2020	IEA (2000)
2001	Deffeyes	2003-2008	Deffeyes (2001)
2002	Nemesis	2004-2011	Nemesis (2002)
2002	Smith	2011-2016	Smith (2002)
2003	Simmons	2007-2009	Simmons (2003)
2003	Deffeyes	Before 2009	Deffeyes (2003)
2003	Campbell	Around 2010	Campbell (2003)
2003	World Energy Council	After 2010	WEC (2003)
2003	Laherrere	2010-2020	Laherrere (2003)
2003	Shell	2025 or later	Davis (2003)
2003	Lynch	No visible peak	Lynch (2003)
2004	EIA	2021-2112	Wood et al. (2004)
2004	Bakhtiari	2006-2007	Bakhtiari (2004)
2004	Skrebowski	After 2007	Skrebowski (2004)
2004	Goodstein	Before 2009	Goodstein (2004)
2004	CERA	After 2020	Jackson and Esser (2004)
2005	Koppelaar	After 2010	Koppelaar
2006	Skrebowski	After 2010	Skrebowski (2006)
2006	Smith	2011	Smith (2006)
2006	Koppelaar	After 2012	Koppelaar (2006)
2006	IEA	After 2030	IEA (2006)
2006	CERA	2035	jackson (2006)
2007	Robelius	2008-2018	Robelius (2007)
2007	Koppelaar	2015	Koppelaar (2007)
2007	Laherrere	About 2015	Laherrere (2007)
2008	CERA	After 2017	CERA (2008)
2008	Shell	2020 or later	Shell (2008)

Table 4 Forecasts of the date peak oil occurs (liberally adapted from Almeida & Silva, 2009)

Regardless of precisely when global peak oil occurs, the above table illustrates that all but one forecaster believes it will occur and many believe it will occur relatively soon. According to Simmons (2005), at least 60 out of 98 oil producing nations of the world are already experiencing declines in their oil production (as cited in Hopkins, 2009).

Part of the complexity in determining peak oil is the limited and sometimes uncertain data available regarding the world's reserve of oil. The causes of this uncertainty are many. For one, the resource is not easily measured. Because oil is below the surface of the Earth, indirect techniques are required to determine the size and recoverability of the reserve (Society of Petroleum Engineers [SPE], 2007). While the oil industry has developed advanced technologies to increase the accuracy of these techniques, there still remains a significant margin of error.

The second complexity in determining a reserve amount is that not all the oil found in a reserve can be recovered (SPE, 2007). In other words, given the current economic conditions, available technology, price of oil, and so forth, only a portion of the oil discovered is economically feasible to produce. The oil industry makes their reserve estimates based on this figure. The problem is that the amount of producible oil for any given field has the potential to change over time. This is the result of technological improvements and techniques such as flooding the well with water, injecting the well with gas, or microbial enhanced oil recovery (MEOR).

Because of these uncertainties in measuring oil reserves, initial reserve estimates tend to be conservative and then expand with time. This makes determining precisely how much oil remains that much more difficult. In addition, the majority of the oil industry does not reveal their actual reserve estimates collected by engineers in the field; instead, they provide un-audited estimates of their reserve base (Cooke, 2004). Unfortunately, the numbers provided by most of the oil industry, particularly OPEC countries, are suspected of being manipulated for political and economic reasons (Hopkins, 2009).

While all this uncertainty has left individual peak oil forecasters in a bit of a predicament, there has been some collaboration to determine the world's remaining oil reserve. In November of 2006, the Hedberg Research Conference on Understanding World Oil Resources took place (Hopkins, 2009). Representatives from across the oil industry attended, as well as representatives from organizations such as the United States Geological Survey (USGS), the EIA, and the International Energy Agency. No press attended the conference, and the presentations that took place were not shared with the public.

The purpose of the conference was to reconcile some of the differences in estimates of future reserves. Companies shared their proprietary data, which is not public information, in an effort to see if there were patterns emerging. The results of the conference were not encouraging. The conference established that non-conventional oils (tar sands, deep water, etc.) will never produce more than 4 to 5 million barrels a day, much lower than the USGS previously estimated. Moreover, the conference estimated just above 250 billion barrels of oil yet to be discovered, which was again much lower than the USGS' previous estimate of 650 billion barrels.

While 250 billion barrels may seem like a lot of oil, much of it may be difficult and expensive, or even impossible, to extract and refine using current technologies and under current economic conditions. Changing economics and technology may allow access to some or all of this oil in the future, but government and investment interests must consider whether new technology should focus on these increasingly complex techniques or instead shift to alternative fuel sources. Broader political and corporate investment shifts could further alter the cost structures of relatively cheap fossil fuels.

In the future, because of the scarcity of cheap extractable oil, petroleum producers will have to face perpetually diminishing returns on invested capital. In addition, operational costs are predicted to escalate as scarcity issues force oil companies to turn to non-conventional sources (i.e., oil sands and shale) – thereby adding complexity and expense to the refinement processes. The immediate problem posed by peak oil is not that the world will suddenly run out of oil, but that the combination of increased demand, reduced supply, and a greater expense to extract and process will drive the world towards much more expensive energy prices, thereby ending the era of cheap energy which provides the basis for much of our current global growth.

Metal Scarcity and Cost

Most materials used by corporations like Boeing have a limited worldwide supply. Metals are mined from the crust of the earth and exist in limited quantities. Many plastics are created from petroleum. Prices for limited resources, such as metals, are expected to increase in the future. Table 5 (following page) presents forecasts for the remaining years of supply of metals given current consumption rates. For some metals, world population growth is likely to increase demand, while for others price increases will reduce demand if substitutes can be found.

The future of metal supplies is further complicated by increasing energy prices. Traditionally, each time the supply of metals has not met demand, production has increased. This has been economically feasible because of cheap energy; however, "due to the scarcity of energy, the extraction rates of most types of metal minerals will cease to follow demand" (Diederen, 2009, p.3). As easily extracted sources of minerals are depleted, the minerals available are often increasingly more energy intensive to extract. This is because the minerals already used or in use were the most economically efficient to extract. In the future, new extraction is likely to take place in "inefficient places," such as the ocean floor.

Furthermore, many of the highest quality sources of commonly used minerals have already been mined, and it is likely that future mining will be directed towards ever-poorer ore grades. Both the mining of lower-grade ores and mining in more extreme locations requires more energy and increases the costs of extraction and processing. The limited remaining supplies of many metals portend significant price increases and reduced availability of raw materials for industrial processes. This will also drive increased reliance on, and cost-effectiveness of, the recycling of metals.

Once again, proactive measures to increase the efficiency, reuse and conservation of resources is an essential tool for controlling cost and supply-chain uncertainties. In addition, companies must consider the social and cultural impacts of resource scarcity, including political destabilization, social unrest, mass migrations and the compounding factor of global climate change, on vulnerable communities that provide the limited resources that remain. Examples of these complex interactions are provided in the following section.

Element	Common Name	Availability Estimates (years)					Aeronautical Applications
		Cohen (2007)	Diedren (2009)	Frondel et al. (2007)	Kesler (2007)	Reller (2007)	
Ag	Silver	29.00	12.00	14.00	10 to 25	9 to 29	Alloying element for aluminum
Al	Aluminum	1027.00	65.00	157.00	>100	510 to 1027	Construction materials: sheet, tube, castings.
Au	Gold	36.00	15.00	17.00	10 to 25	36 to 45	Semiconductors, corrosions resistant electronic wiring
Be	Beryllium	n/a	>70	n/a	n/a	n/a	Inertial guidance systems, turbine blades, rocket engine liners, springs, aircraft brakes, ball bearings, electrical contacts, electrical components, gears.
Cd	Cadmium	n/a	20.00	n/a	n/a	n/a	Electronics
Co	Cobalt	n/a	59.00	135.00	50 to 100	n/a	Alloying element
Cr	Chromium	143.00	>70	46.00	>100	40 to 143	Alloying element for (stainless) steel, nickel and aluminum alloys, used as a surface coating to prevent oxidation
Cu	Copper	61.00	25.00	32.00	25 to 50	38 to 61	Piping, electrical applications, alloying element for aluminum alloys
Fe	Iron	n/a	48.00	119.00	>100	n/a	Construction of machinery and machine tools, buildings
Hg	Mercury	n/a	24.00	n/a	n/a	n/a	Fluorescent lamps
In	Indium	13.00	18.00	7.00	>100	4 to 13	Vacuum Seals, (e.g. airplane windows), LCD screens
Li	Lithium	n/a	>70	203.00	>100	n/a	Alloying element for aluminum, batteries
Mg	Magnesium	n/a	>70	515.00	>100	n/a	Electronics, alloying element for aluminum, removal of sulphur from iron and steel, refining of titanium, additive agent in cast iron
Mn	Manganese	n/a	29.00	41.00	25 to 50	n/a	Alloying element for steel and aluminum, batteries
Mo	Molybdenum	n/a	33.00	n/a	25 to 50	n/a	Alloying element for steel
Ni	Nickel	90.00	30.00	44.00	50 to 100	57 to 90	Alloying element for steel, super alloy
Pb	Lead	42.00	19.00	21.00	10 to 25	8 to 42	Batteries, semiconductors
PGM	Platinum	n/a	n/a	n/a	n/a	42 to 360	Fuels cells, catalysts
Sn	Tin	25 to 50	17.00	23.00	25 to 50	17 to 40	Steel coating
Ti	Titanium	n/a	61.00	130.00	n/a	n/a	Alloying element, structural parts, fire walls, landing gear, hydraulic systems
Zn	Zinc	10 to 25	15.00	23.00	10 to 25	34 to 46	Galvanization, alloying element, batteries

Table 5 Forecasted Mineral Availability

Water Scarcity

Water scarcity is a financial, environmental, and social obstacle to sustainable business growth. The physical supply of freshwater worldwide is limited, access to freshwater is inequitable, and pressures on water systems are growing. Freshwater supplies are integral to worldwide irrigated agriculture and industrial processes that enable and encourage all global business. Business is thriving thanks to subsidized infrastructure and widespread access to these resources. Yet socially, water scarcity affects one in three people on 6 continents, limiting access to food, prohibiting basic sanitation, and promoting the spread of food-borne, infectious, and parasitic diseases. These problems will intensify with population growth and urbanization, increasing water use and making scarcity more acute (Geller, 2009).

Effective responses to water scarcity must encompass local, regional, and global impacts. Fundamentally, water scarcity occurs in localized ecosystems and has direct, localized impacts. However, globalization has increased connectivity between regions and countries to the point that local problems such as water scarcity can influence global supply chains and global business strategy. Physical and/or economic water scarcity currently affect China, India, Australia, Turkey, South Africa, Egypt, Bolivia, the southwest United States, and all of central Africa, to name a few (International Water Management Institute, 2008).

Influence on Production Costs

Local water conditions can influence costs up and down the supply chain due to physical and social water management needs. As water resources become depleted, new physical infrastructure is necessary to dig deeper, travel farther, and more thoroughly research new water sources to supply workers and machines at manufacturing and extraction sites. Alternatively, infrastructure can be inundated by rising sea levels from melting ice caps and increased runoff, requiring new investment. Changing precipitation and erosion patterns will also influence freshwater supply and quality. The resulting cost increases can occur anywhere along the supply chain (United Nations Global Compact, 2009). For example, the cost of aluminum will increase if water scarcity or contamination forces new investment in bauxite mining, alumina extraction, or aluminum refining. Silicon chips are another example: their production requires significant amounts of clean freshwater, yet 11 of the world’s 14 largest semiconductor factories are located in Asia-Pacific, a region already experiencing water scarcity (Lubber, 2009).

Water scarcity can also precipitate political and social unrest that alters industrial pricing models. The nation of Guinea, which holds almost half of the world’s bauxite reserves, provides an example of this problem. Social unrest in Sierra Leone and Liberia, immediately south, has already spilled over into Guinea, worsening economic conditions there (CIA, 2007). Meanwhile, desertification in the Sahel desert continues to Guinea’s north and east, resulting in water scarcity and increased migration. This begins a vicious cycle, as migrants increase strain on regional economies and ecosystems. That strain leads to further resource depletion, allowing desertification to spread, and requiring further migration (de Troyer, 1986).

These factors came to a head in September 2009, when a bloody coup enveloped Guinea's capital. As a result, the nation's aluminum production is down 20%. This depletes foreign investment, threatening further social collapse (Magnowski, 2010). While Guinea's instability is not solely a result of water scarcity, it clearly demonstrates how social and environmental inequities can have devastating long-term, cumulative effects that extend all the way to the financial bottom line. A truly sustainable approach to global business must effectively address these complex interactions.

Influence on Social Costs

New costs could also result from social management needs. Even if a locality has sufficient water resources for industry, access can be restricted due to social requirements. For example, population growth in an Australian town that supports bauxite mining could increase demand for local freshwater. Resulting regulations that reduce industrial water subsidies or set stricter limits on industrial water use to satisfy community demand will increase the cost of the end product (Ohlsson, 2000).

These social strains can also come from degraded agricultural systems. Israel, Egypt, and Morocco, for example, are being forced to import more grain as their water scarcities reduce crop production. This, in turn, places more pressure on stable agricultural land. Avoiding the long-term and cumulative impacts of this cycle, including famine, violence, and forced migration, depends almost entirely on the response of developed nations (Yang & Zehnder, 2001). Eventually, global food production will depend on global water management, with restrictions being placed on industry both domestically and internationally. Proactive research and development of new industrial processes that minimize water use and strategically manage existing resources are absolutely necessary. New innovations will reduce the risks companies face and increase adaptability to unpredictable future market conditions.

This vulnerability is also increasingly relevant to corporate reputations. Risks will increase as awareness of social and ecological impacts continues to expand. Steps are already being taken to detail the effects of industrial consumption patterns on the global hydrological cycle (Ridoutt & Pfister, 2009). In Kerala, India, for example, a beverage company put undue strain on local groundwater supply, leading to revocation of their operating license, reduced revenue, and a damaged reputation (United Nations Global Compact, 2009). As scarcity grows more severe, these examples are likely to become more numerous and influence global supply chains, especially those that depend on socially, economically, and environmentally exploited regions of the world, including Southeast Asia, west-central South America, and the entire African continent. Sound water management strategies must consider indirect environmental and social costs that influence the long-term viability of supply chains (Seneviratne, 2006).

Regions affected by drought and water scarcity are also more likely to experience high population growth, climate fluctuations, droughts, and widespread poverty (Cheboi, 2010). These problems compound each other, adding to social instability. A growing body of research and information is leading to increased global awareness of this acute inequity. Water scarcity has already been linked to declining food production, increased disease, and social instability (United Nations Global Compact, 2009). While it is impossible to predict where and when these issues will influence global business, there is no doubt that globalization has increased corporate vulnerability to these local and regional instabilities.

Solutions

To fully understand these connections and integrate them into a sustainable business model, Life Cycle Analysis (LCA) is an essential tool and driver of innovation. It is also a required component of the ISO Environmental Management System, to which Boeing has committed in their Environmental Report (Boeing, 2009). Less comprehensive models fail to account for resource consumption and scarcity at all levels of a supply and distribution chain. Particularly in the case of water management, LCA must be segmented to consider uses at regionalized scales of product development. Because water is less mobile than energy, and scarcity cannot be “offset” at other stages of the supply chain, regional considerations are essential (Reich-Weiser & Dornfeld, 2009). Total water use for a product is insufficient and will not account for long-term vulnerability at a specific link of the supply chain. The result is in an incomplete water footprint and an inability to assess long-term viability of that chain.

Conservation and careful stewardship of freshwater supplies, including reuse and reduced consumption, will become increasingly important. Boeing must consider availability of water supply when locating new plants and relocating existing ones. Because of the localized nature of water scarcity, it could threaten cost and reliability of Boeing's global supply chain, even if Boeing’s own facilities are responsibly built and managed. Conservation, the efficient use of water, and strategies for re-use will be critical to future corporate sustainability worldwide. As scarcity drives up the cost of water and energy in local economies, the cost of water-heavy manufacturing and production operations will likewise increase over the long-term.

In addition to physical water supplies, all water involves embodied energy. Energy is used to pump water from the ground, purify it, pump it to the point of use, heat it, and pump post-consumer water back to treatment facilities, where it is again treated prior to release. Each of these steps requires infrastructure, management, and energy input. Just as water has embodied energy, energy has embodied water. All large-scale energy production facilities are significant users of water. In fact, water and energy are so intertwined as to be almost inseparable in their environmental footprints (United Nations Global Compact, 2009). One implication of this is that as energy prices increase in the future, the cost of water will increase as well.

While Boeing has spent considerable resources on energy, there is little evidence of long-term investment in water efficiency and conservation in production facilities or along its supply chain. These investments are an excellent opportunity to save money and resources in both water and energy. As access to freshwater becomes limited for production facilities, corporate strategies and innovative technologies promoting low-water and no-water production will move from opportunity to necessity. Social instability and inequity is likely to accelerate the need for such investment.

Understanding the connections between water use, energy, and greenhouse gas emissions will help realize opportunities to reduce water consumption. New efficiencies will conserve water, reduce energy use, and lower greenhouse gas emissions. Sustainable production and consumption requires broad, sweeping changes in the way business models are conceived and executed. Taking a leadership role reduces long-term risks, increases adaptability, and broadens new horizons for innovative businesses.

Greenhouse Gas Emissions

The science on climate change continues to develop, continuously leading to a better understanding of the earth-climate system and fine-tuned forecasts of the effects of anthropogenic climate impacts. It is well known that aviation impacts the atmosphere considerably, although more research will be needed to determine the magnitude of that effect.

The contributions to climate change made by aviation are more complex than those of ground transportation, going beyond a singular concern for carbon emissions (mainly CO_2) to include the effects of NO_x, SO_x, soot, and contrail water-vapor emissions. Combined, these emissions have a greater impact on climate than carbon emissions alone. For the period “from 1992 to 2050, the overall radiative forcing by aircraft (excluding that from changes in cirrus clouds) is a factor of 2 to 4 larger than the forcing by aircraft carbon dioxide alone” (Intergovernmental Panel on Climate Change [IPCC], 1999). ‘Radiative forcing’ is a unit quantifying the “Greenhouse Effect,” expressed in W/m^2.

Furthermore, these impacts are disproportionately large compared to other human activities, for which the “overall radiative forcing for the sum of all human activities is estimated to be at most a factor of 1.5 larger than that of carbon dioxide alone” (IPCC, 1999). This illustrates that the combined environmental footprint of global aviation is considerably larger than that of its CO_2 emissions alone.

However, considerable uncertainties about aviation’s impact on climate remain. In their report on aviation and the climate, the IPCC found a high degree of uncertainty in their estimated aviation impacts, concluding that “the total radiative forcing may be about 2 times larger or 5 times smaller than the best estimate” (1999). This uncertainty comes from our limited understanding of several of the atmospheric processes disrupted by jet-engine emissions. In this context it should be noted that even the lowest estimates of radiative forcing caused by aviation are alarmingly high when considered as absolute quantities.

Carbon Dioxide and the “Greenhouse Effect”

The behavior and effects of carbon dioxide in the atmosphere are well understood. CO_2 is the major reaction product (together with water) of the aerobic combustion of organic compounds such as petroleum-based fuels. When residing in the troposphere (lower atmosphere), CO_2 absorbs radiation in the infrared region of the spectrum, including heat emitted by the planetary surface. This heat is then re-emitted in all directions by the CO_2 molecules, and a large part of the heat is directed back to the surface. The net result is the “greenhouse effect.” Before the Industrial Revolution, the greenhouse effect from the “naturally occurring” gases in the atmosphere facilitated a stable climate suitable for life. After the Industrial Revolution, however, the rapidly increasing emissions of CO_2 and other radiatively active gases have contributed to a rising global mean surface temperature.

No ecosystem on Earth is adapted to respond to this change on the timescale of decades or even centuries. Slower changes would be more effectively mitigated by negative feedbacks, such as increased carbon sequestration (retention) by increasing plant growth. At present, we are instead witnessing a large number of positive feedback loops interacting to speed up the net heating of the Earth's climate system. This includes the loss of polar ice due to rising temperatures, causing a lowering of the albedo (reflectiveness) of non-terrestrial regions. This in turn results in larger absorption of atmospheric heat by the ocean when less radiation is reflected back into space. As more examples emerge in scientific literature, the direct and indirect impacts on "business as usual" will become increasingly potent and clear.

Nitrogen Oxides (NO_x)

The atmospheric chemistry of the nitrogen oxides (NO and NO_2—jointly termed NO_x) is highly complex and influential on the climate. After carbon (CO_2 and CO) and water, NO_x is the most abundant jet-engine emission. It is estimated that the NO_x released by aviation into the stratosphere contributes between 20 and 40% of total global NO_x emissions into the stratosphere (Hoinka et al., 1993; Baughcum, 1996; Schumann, 1997; Gettleman & Baughcum, 1999).

Many uncertainties exist surrounding the behavior and net effects of atmospheric NO_x. NO and NO_2 are greenhouse gases, contributing directly to climate change. The most critical atmospheric impact of NO_x emissions caused by subsonic aviation is a disturbance of a complex chemical cycle which results in increasing ozone (O_3) in the upper troposphere and lower stratosphere, as well as (theoretically) a reduction of methane (CH_4), another important greenhouse gas. The latter has not been observed, however (IPCC, 2009; Stevenson & Derwent, 2009; Köhler et al., 2008).

When ozone is located in the upper stratosphere it shields the planetary surface from UV radiation. However, when O_3 resides in the lower regions of the atmosphere (the troposphere) its net effect is a contribution to global warming. The NO_x emissions in the upper atmosphere (18 km or above) caused by supersonic aviation result in a net decrease of ozone, which means a depletion of the ozone layer. Therefore, the abundant NO_x emitted by jet engines not only amplifies climate change but also disrupts the ozone layer.

The identification and quantification of background NO_x sources and sinks is still incomplete. Although the NO_x contribution by aviation is large in absolute terms, this uncertain background makes the assessment of the relative NO_x impact of aviation problematic (IPCC, 2009). The overall complexity associated with atmospheric NO_x (together with sparse long-term data) further complicates modeling (IPCC, 2009).

Carbon monoxide (CO) emissions from aviation occurs at the same atmospheric level as NO_x. CO also produces tropospheric ozone, but is considered to have an impact of lower relative magnitude due to the "background" abundance of CO from global fossil-fuel combustion (IPCC, 2009).

Aerosol Emissions: Water, Sulfur, Soot, and VOCs

Yet another source of climate disruption is water aerosol emitted by jet engines. These aerosols contain several compounds that disrupt atmospheric chemistry. In the form of contrails and cirrus clouds, the aerosol water in itself contributes to considerable radiative forcing, possibly equal to or greater than the forcing contributed by aviation CO_2 emissions.

Jet-fuel sulfur, together with soot and various volatile organic compounds (VOCs), is mainly released as a particulate-matter aerosol (a fine mist) suspended in the contrail water. The sulfur in jet fuel is mainly emitted as SO_2 and a small proportion as sulfuric acid (IPCC, 1999). The residence time of these sulfur compounds in the troposphere is short and they are quickly scrubbed out by precipitation and deposition processes (IPCC, 1999). In the stratosphere they linger for longer periods of time.

Aviation aerosol emissions are very difficult to model since the ambient background of atmospheric particulate matter varies locally and seasonally. The net effect of water/sulfur/carbon-compound aerosols emitted by aviation in the troposphere is believed to be a decrease in ozone levels.

The chemistry of atmospheric soot is very poorly understood. IPCC (1999) concluded that the impact of soot on atmospheric chemistry is likely to be small. The soot can potentially destroy stratospheric ozone, but the overall soot concentrations resulting from aviation emissions are believed to be too small to cause any significant effect. The IPCC also found the direct climate impact by aviation sulfur emission (beside the effect on cloud nucleation) to be low (1999).

Contrails and Cirrus-Cloud Formation

The most severe climate effect of the stratospheric emission of jet-engine aerosols is radiative forcing caused by (linear) contrails and cirrus formation. The cirrus formation occurs when the particulate matter in the aerosol provides condensation nuclei which facilitate cloud formation (i.e. the freezing of the contrail water) (IPCC, 1999). Water vapor in itself is a powerful greenhouse gas. Dense clouds can reduce the total radiative forcing by reflecting back a larger amount of insolation (incoming short-wave radiation from the sun) to space than the amount of heat that is trapped by the radiative forcing of the water vapor in the clouds. High-altitude cirrus clouds however can increase the net radiative forcing by trapping heat in the form of infrared radiation re-emitted from the Earth surface while at the same time having a limited reflectivity blocking out insolation.

Although more research is needed, it is well known that the climate impacts of contrails and aviation-induced cirrus clouds are of a magnitude that may exceed the impacts of CO_2 emitted by aviation on the global scale.

The IPCC 1999 Report Contrasted With More Recent Data

Sausen et al. (2005) compared the radiative-forcing data of the IPCC 1999 report with the findings of the EU FP5 research project TRADEOFF (2000-2003). The 2003 mean values of CO_2, O_3, CH_4, H_2O, direct sulfate, and direct soot were close to the 1992 values reported in IPCC (1999). All of them, except CO_2 (which is slightly higher), are within the 2/3 confidence bounds (67% probability ranges) of the IPCC values from 1992. The total radiative forcing from the six parameters in 2003 was very close to the reported 1992 data (as well as interpolations made from the trends forecasted in the IPCC report).

The major difference between the TRADEOFF estimates and the IPCC estimates and forecasts is in the effect of linear contrails. The mean 2003 contrail forcing was found to be lower by an approximate factor of 3-4 compared to the mean estimate for 1992 by IPCC (2001). However, since the absolute number value remains very high, even the downgraded estimate of contrail forcing should be a cause for concern. The TRADEOFF study found the scientific understanding of contrail forcing to be “fair” and that of cirrus-cloud forcing to be "poor." Sausen et al. (2005) concluded that in itself, the forcing contributed by contrail-induced (or modified) cirrus clouds can be up to three times that of aviation CO_2 emissions. The research published since the IPCC (1999) report gives us reason to believe that the climate impact of aviation aerosols is significant. The combined direct (contrails) and indirect (cirrus formation) effects of these aerosols probably exceed the impacts of total aviation CO_2.

Recommended Mitigation: Reduce NO_x and Aerosol Emissions

The major remaining uncertainty, acknowledged in both the IPCC (1999) report and the TRADEOFF study, is the effects of cirrus clouds created or modified by contrails. It is possible that the effect of these clouds could *double the total radiative forcing of global aviation*. For this reason, more research on aviation and cirrus formation is a priority. The available literature on the climate impact of contrails and contrail-induced cirrus clouds was reviewed by Burkhardt et al. (2008).

Since it is well known that water vapor introduced into the stratosphere by jet engines is a major contributor to climate change, Boeing should make it a priority to develop engines with minimal emissions of water and particulate matter. Although it is generally acknowledged that reduction of water emission from jet engines poses a considerable engineering challenge, this needs to become a priority for the industry. The IPCC has recommended mitigation strategies focusing on minimizing radiative forcing from contrail aerosols (1999). The demand for technology solving these problems is likely to emerge rapidly with the growing awareness of contrail-induced radiative forcing.

A reduction of jet-engine NO_x emissions could further decrease the climate impact of aviation considerably. As of today, a regulation of aviation NO_x appears to be the next likely regulative step in the EU Emission Trading Scheme following the regulation of CO_2 emissions (Marbaix et al., 2009).

Increased engine efficiency by improved combustion could also reduce the production and emission of particles that function as condensation nuclei, including soot and volatile compounds. Increased engine efficiency would also likely decrease the proportion of carbon emitted as CO. Contrails formed with less particulates cause lower radiative forcing (IPCC, 1999). Beyond increasing jet-engine efficiency, Boeing has the opportunity to assume a leading role in reducing contrail water aerosols and NO_x emissions.

As political grandstanding and posturing delays a meaningful response to climate change, it also increases the intensity of the response that will be needed. While short-term politics and a lack of a coherent plan for emission reductions make it difficult to predict outcomes over the next few years, the scientific understanding of the causes and effects of climate change is becoming more coherent and the impacts more noticeable. At some point, a response proportionate to the scale of the problem will be necessary and unavoidable. When this occurs, the company that succeeds in reducing the overall climate impacts of aircraft, including emissions of NO_x and water vapor in addition to CO_2, will have a competitive advantage.

The Uncertainty of Biofuels

The issues of oil scarcity and fossil-fuel related climate forcing have motivated a search for alternative fuels. Aviation, with its dependence on liquid fuels, will be vulnerable to any limitations imposed on fossil-fuel use. In recent years, much attention has been directed to potential "biofuels," including jet fuel produced from various plants and microorganisms. The idea is to find an organism, or an organic waste product such as a plant residue, that can be converted into a high-energy yield fuel with a climate impact that is lower than that of fossil fuels.

A number of potential biofuel sources have been considered for industrial-scale feedstock development. Political decisions have been made by various nations to gradually transition to an energy mix including biofuels. The European Union, in particular, has put extensive trust in the future sustainability of commercially developed biofuels (Gnansounou et al., 2009). In the United States, the Energy Independence and Security Act of 2007 (US Congress, 2007) has mandated an energy mix including 36 billion gallons of renewable fuel by the year 2022 (including 16 billion gallons of cellulosic ethanol).

Several airlines, including Virgin Atlantic Airways, Air New Zealand, Continental Airlines, Air Japan, and Boeing, have conducted successful test flights with plant-based biodiesel mixed with regular jet fuel (Ritch, 2009). Research on the sustainability of biofuels, however, is beginning to show that initial enthusiasm may be unfounded. Developing biofuels sustainably on an industrial scale proportional to society's present demand is difficult for a number of reasons.

Biofuel Crops

The complexity of large-scale biofuel production is already a damper on industrial development. This is especially true for the "wonder weed," *Jatropha curcas,* that a few years ago was promoted with great vigor (the Boeing Environmental Report presents it as a major biofuel crop of the future). The initial idea was to grow *Jatropha* on land not presently used agriculturally in developing countries under very dry conditions. The problem is that *Jatropha* yields have been found to be much lower than expected under sub-optimal moisture regimes. For this reason, the plant may not be commercially interesting as a biofuel feedstock, and major investors have already abandoned their investment plans in the crop (Sanderson, 2009). The oil plant *Camelina* may become problematic agro-economically for the same reasons. It is possible that selective breeding will eventually result in higher-yielding cultivars, but how and when this will impact the sustainability of biofuel production is impossible to forecast.

The interest in *Jatropha* highlights another major problem with land-grown biofuel feedstocks: displacement of food crops. The hope was that *Jatropha* would not compete with food crops for land (Sanderson, 2009). This is unlikely, however, if oil-seed crops become more commercially interesting to growers than food crops. If oil-crops are to be grown on a scale needed to displace fossil fuels, then they have to be commercially and economically viable for growers. As a consequence, food cropping will suffer and land will be reallocated to plant-oil production, resulting in rising food prices. In the case of *Jatropha*, this would occur even if the plant could be grown under dry conditions. Since it would produce higher yields with increased irrigation, this would make it an interesting alternative crop for present food-crop growers that may abandon food production for increased profit.

In the case of biodiesel derived from transesterified soybean oil, the land-use related problems have become even more pronounced. When the recent increasing demand for soybean oil for biodiesel made its price go up, food-crop land was reallocated to growing soya, and rainforest in Brazil was slashed-and-burned for the profitable soybean agriculture (Grunwald, 2008). This vicious cycle of unintended consequences shows how difficult it is to develop a land-grown biofuel with simultaneous economic and environmental sustainability.

Climate Impacts

Maier et al. (2009) reviewed the literature on how the production and utilization of biodiesel impacts the climate. They found that if natural land was not converted to agricultural land in the process, then the utilization of some biofuel crops may result in moderate to good GHG reductions. However, they also noted that different life-cycle assessments gave divergent results. Using a global agricultural-systems model to estimate GHG emissions caused by land-use change, Searchinger et al. (2008) found that a wide-scale implementation of biofuels could increase total GHG emissions. The authors of the widely discussed study also found that corn-based ethanol would nearly double 30-year GHG emissions, and result in increased GHG emissions for 167 years. Because of land-use change, biofuels produced from switchgrass could increase emissions by 50%.

A recent USDA energy life-cycle study of soybean biodiesel suggests that its fossil-energy ratio (FER) is gradually increasing over time due to improved production systems and higher-yielding cultivars (Pradhan et al., 2009). However, a preliminary report of the GHG life-cycle analysis of the same biofuel conducted by the EPA (2009) predicts a 4% increase in GHG emissions on a 30-year timescale as compared to gasoline and diesel. On a 100-year timescale, the same biofuel is predicted to yield a 22% reduction in life-cycle GHG emission. The analysis conducted by the EPA incorporates a model of indirect land-use change. Of the land-grown biofuel crops, the EPA expects life-cycle GHG emission reductions on a 30-year time scale from sugarcane and switchgrass ethanol, assuming that these crops do not compete with food production.

Plant-based biofuels may displace additional atmospheric CO_2 from fossil-fuels under careful land-use conditions. Nevertheless, the globalized commodities market makes the conversion of pristine land to agricultural land seemingly inevitable under conditions where biofuel crops are economically sustainable. And the global need for growing food is constantly increasing with a growing world population, while at the same time the global demand for energy and liquid fuel is constantly increasing. The sustainability of all energy and fuel systems has to be considered in light of these conflicting needs and the global social-equity issues that come with them.

Alternative Biofuels

An alternative to land-grown biofuels may be the use of algae and microorganisms as biofuel sources. The research on algae-based fuels is promising in theory, but no large-scale production system has yet been designed. The challenge is to scale up production from laboratory glassware to commercial levels within a relevant timeframe (Mascarelli, 2009). Production infrastructure is lacking, and the future economics of any algae-based biofuel are uncertain. The research in the field is still in the infant stages. The largest investment in algae-based biofuel so far has come from ExxonMobil, which has formed a partnership with Synthetic Genomics (co-founded by Craig Venter) (Mascarelli, 2009). There are many ethical issues that surround the use and commercialization of transgenic organisms, which may or may not impact its market viability.

Another alternative to oil-crop biofuels is the derivation of fuel from cellulosic biomass, such as slash piles remaining after tree harvest. Several strategies for commercial development have been proposed. A major obstacle to overcome is the limited cost effectiveness that comes with long-distance transportation of wood residue to a facility for conversion (O'Laughlin, 2009; Stevenson et al., 1999).

Pyrolysis (conversion by airless heating) of forest biomass has been suggested as a method to circumvent this problem and to increase the life-cycle environmental sustainability of biomass-derived fuel (Laird, 2008). The idea is to create a system, situated near the location of tree harvest, that converts the bulky forest biomass into synthetic gas, liquid bio-oil, and solid residual charcoal or biochar. These products have a higher energy density than forest biomass. Ideally, a cost-effective mobile system could be created that renders obsolete large, centralized facilities that require scaling and accessibility.

When it comes to supplying the future liquid-fuel need for aviation, biofuels of some form may come to play an important role. However the scale of aviation-fuel need in itself makes the sustainability of the necessary commercial developments highly uncertain.

Waste Stream Costs

In a resource-limited future, waste will have unaffordable economic and environmental costs. Existing landfill space is decreasing, and situating new landfills will become increasingly difficult and costly. In addition to tipping fees, the costs associated with transportation of waste will increase proportionately to increasing fuel prices. Motivators to decrease waste include not only the cost of transporting and disposing of waste, but also the expected increase in the cost of many materials. As resource scarcity increasingly constrains material availability and increases costs, waste will likely be seen as corporate, national, and global assets being thrown away.

Reduction in use through conservation, thoughtful minimal use, re-use, re-direction of waste streams into other production processes, and recycling are practices already being used at Boeing, and it will be important to expand their application in the future. It is less clear from Boeing reports that redesign of products and processes to eliminate the creation of waste is taking place at the levels possible and desirable.

There is much discussion in the 2009 Environment Report about recycling of materials, but little to none on waste minimization. This is usually accomplished by the reduction of materials waste through production redesign and pre-consumer reuse of materials (although this may be included internally under recycling). The overall guiding framework should not be to increase recycling, but rather to reduce the production of waste. The goal is zero waste; although this represents an ideal situation, dramatic reductions in the short-term are possible.

Both eco-efficiency and cradle-to-cradle models of material flows conceive of waste streams as feedstock for other processes. Efforts should be made to determine if additional products can be developed using existing waste streams as feedstock, whether at Boeing or at potential partners.

For organic materials this may mean converting them into plastics, fuels, or soil amendments. For metals and plastics this may mean recovering them for reuse. Boeing's involvement in aircraft recycling makes it possible to integrate information learned during the disassembly and recycling process back into the design process for new products. Based on this information, re-design should be implemented to maximize both substitution of materials and efficiency of materials-recovery during disassembly. This process can also be used to eliminate materials that cannot effectively be reprocessed.

Office environments are another area for potential gain. Double-sided printing and copying, converting to electronic formats whenever possible, and developing purchasing policies intended to minimize disposable material streams are cost-effective strategies to reduce waste, while also promoting an ethic of minimization and recycling in all areas of company operations, not just in production operations.

Embracing a low- or zero-waste philosophy and reaping the benefits of lower energy, water, and material consumption will result in significant long-term savings to the corporation. This will also result in an increased ability by Boeing to respond to potential downward pressures on product pricing. Many companies have turned waste streams into revenue sources through collaboration with other industries. Considering the size and scope of Boeing's industrial manufacturing, this is likely a major opportunity to integrate environmental and corporate responsibility.

Local and Regional Planning

As an operator of large corporate and industrial campuses, Boeing has an opportunity to use its own facilities as living laboratories in the same way a university does. Every building, every facility, and every product provides an opportunity to implement the most cost-effective and sustainable designs and technologies. As future energy prices rise, Boeing will continually reap the benefits of progressive investment.

In addition to rising costs, the future also brings increased risks of volatile economic and supply-chain costs. High performance buildings are more cost effective in terms of total cost of ownership over the life of a building. Their reduced operational costs save money over time, and reduce vulnerability to future increases in energy, water, and other costs. The ultimate goal is waste-free, net-zero energy buildings, which use alternative sources to create as much or more energy than they use, eliminating dependence on energy grids and even creating new revenue streams. New technologies and integrative design processes continue to drive sustainable buildings, providing a unique opportunity to minimize cost and resource use while creating new revenue streams.

In order to realize the benefits of energy-saving technologies, facility management needs to be optimized. To do this, long-term data must be collected from the design phase of the process through the life of the facility. Buildings need to be re-commissioned regularly to optimize operation of equipment and ensure design features are being used to maximize efficiency. To adequately optimize facility operations, more data needs to be collected on building performance than is conventionally collected. A number of different building information systems are available. A small investment in building information systems that routinely collect and process data necessary for facility operation allows significant savings through more efficient operation of buildings.

The role of facilities in local and regional economies and communities will also become increasingly important over the next few decades. Boeing needs to be sure that they consider facilities carefully in terms of local, urban, and regional planning issues. Commuter transportation is one such area in which broad changes are expected. The costs of transportation systems centered on single-occupant vehicles are becoming much better understood. Discussions of sustainable transportation systems typically include moving away from the publicly-subsidized automobile system currently used in the United States and towards better utilization of public transit and alternative transportation, as well as increased telecommuting.

Another impact associated with facility location is the effects of location on urban sprawl. A number of companies, including Sprint and GAP, have built extremely progressive buildings in poorly chosen locations. Initially praised for their progressive architecture, both companies are now being criticized for the overall impacts of the facilities. The sprawl and transportation problems caused by both companies outweigh the “green” building benefits exhibited in their architecture because they did not adequately incorporate urban and regional planning issues in their facility design (c.f. Owen, 2009).

The current U.S. economy is dependent upon cheap fossil fuels and publically-subsidized ground transportation infrastructure. Comprehensive changes in the current ground transportation systems should be expected. The trend will not be monolithic, and globalization will continue, but a trend towards building local and regional economies and communities, and local and regional strengths and resiliencies, will grow and broaden as well.

CONCLUSIONS

Boeing is a successful, worldwide corporation that cannot afford to underestimate the trends that are pushing the world toward more economic, environmental, and social sustainability. Boeing has made great strides toward becoming a more sustainable corporation. Many opportunities for improvement still exist and implementation will result in a stronger long-term corporate economic model: more careful and economic use of energy, water, materials, and a transformed view of waste. Increased sustainability will be necessary for Boeing to continue its global leadership role and maintain its competitive advantage.

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Appendix A EIA Forecasted Energy Prices

*Adapted from the EIA's (2009) Annual Energy Outlook

EIA's Forecasted Energy Prices by Sector and Source-2009 (Nominal Dollars per Million Btu, Unless Otherwise Noted)

Sector and Source	Reference Case					Annual Growth 2007-2030 (percent)
	2010	2015	2020	2025	2030	
Industrial						
Liquefied Petroleum Gases	23	32.62	37.17	40.49	44.93	2.9%
Distillate Fuel Oil	16.68	25.57	29.14	32.67	36.52	3.4%
Residual Fuel Oil	16.2	23.64	27.05	29.57	32.95	5.1%
Natural Gas	7.27	8.11	9.66	11.03	13.16	2.5%
Metallurgical Coal	4.6	5.09	5.69	6.28	6.4	2.5%
Other Industrial Coal	2.67	2.98	3.27	3.55	3.88	2.0%
Coal to Liquids	n/a	1.4	1.59	1.81	1.98	n/a
Electricity	19.72	21.2	24.63	27.71	31.3	2.3%
Transportation						
Liquefied Petroleum Gases	27.04	37.06	42.13	45.7	50.41	3.1%
E85	26.83	29.51	37.85	41.04	43.63	2.2%
Motor Gasoline	24.72	33.26	38.43	42.32	46.54	3.1%
Jet Fuel	16.89	24.86	28.62	31.7	35.7	3.5%
Diesel Fuel (distillate fuel oil)	21.12	29.78	33.63	37.48	41.44	3.0%
Residual Fuel Oil	12.74	19.76	22.56	25.02	28.49	5.0%
Natural Gas	15.69	17.03	19.24	21.08	23.55	1.8%
Electricity	31.95	34.91	38.09	43.63	49.51	2.1%
Electric Power						
Distillate Fuel Oil	15.89	23.03	26.42	29.36	33.51	3.6%
Residual Fuel Oil	13.91	21.05	23.97	26.57	29.97	5.7%
Natural Gas	6.94	7.77	9.24	10.67	12.61	2.6%
Steam Coal	1.99	2.25	2.48	2.7	2.95	2.2%
Non-Renewable Energy Expenditures (billion of nominal dollars)						
Industrial	215.12	282.68	313.49	349.53	400.54	2.5%
Transportation	611.87	850.99	972.48	1075.67	1237.08	3.2%
Total Non-Renewable Expenditures	1256.84	1635.24	1894.47	2131.06	2459.36	3.0%
Transportation Renewable Expenditures	0.07	10.38	32.08	69.93	95.27	40.1%
Total Expenditures	**1256.91**	**1645.62**	**1926.55**	**2201**	**2554.63**	**3.2%**