GLOBAL WARMING: IS IT REAL?

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Global Warming: Is It Real?

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Global Warming: Is It Real?

Until recently, the issue of global warming appeared to be very controversial. There were, and in some cases still are, critics and skeptics in both politics and science who simply did not believe global warming was taking place on such a massive scale. Mainly due to a lack of scientific evidence, their conclusion on this subject was that global warming was a natural process which takes place on Earth in cycles over a number of years. Today, global warming is an issue that does not involve much controversy in terms of its existence. However, the argument over the causes, impact, and responsibility of global warming is still a hot topic.

This thesis will attempt to answer the question, "What are the primary causes contributing to global warming, and what measures are necessary to reduce global warming in the future?" The thesis will also examine the other issues surrounding the topic of global warming, such as the economic, ethical, and social responsibilities which are involved.

Global warming is a phenomenon which has been occurring over the past 15,000 years on Earth. It can be described as a struggle between human progress (in the form of industrialization, population increase, and economic growth) and nature. The process of global warming occurs when greenhouse gases (primarily CO_2, NO_2, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride) are released into the atmosphere. These gases continue to increase in concentration in our atmosphere creating a “greenhouse-like” effect by trapping in heat from the sun, resulting in an increase in Earth’s average temperature. If left unchecked, the buildup of greenhouse gases could permanently alter Earth’s ecological systems. This would have drastic consequences for the planet’s biodiversity, including the human race. Current studies from the International Panel on Climate Change (IPCC) indicate that Earth’s surface temperatures could rise by 3.8 to 11.2 degrees Fahrenheit over the next 50 years, based on current greenhouse gas (GHG) emissions (Motavalli, 2003). This increase in temperature would have profound effects across the globe, ranging from increased sea-levels, more severe storms, and the melting of large glaciers and icebergs. These changes in nature would in-turn produce devastating results in the form of floods, loss of plant and animal life, more frequent droughts and famine, and a greater risk of human casualties in all parts of the world.

In order to prove that global warming is in fact taking place, scientists first had to show evidence that the Earth is becoming warmer. The most reliable and accurate evidence they found lies deep inside glaciers, in the form of ice core samples. Scientists can drill out core samples from glaciers and determine the GHG concentrations in Earth’s atmosphere from 400,000 years in the past (Motavalli, 2003). Their data reveal that the level of CO_2 has been steadily rising for the last 15,000 years, and most dramatically since the Industrial Revolution first began pumping large quantities of CO_2 into the atmosphere (Motavalli, 2003). Studies from the University of East Anglia show that the temperatures in the Northern Hemisphere from 1970 to present have been the warmest years in the past 1,000 years (Motavalli, 2003).

Willi Dansgaard, Claude Lorius, and Hans Oeschger are three scientists who have documented more than 150,000 years of global climate change by analyzing glacial ice core samples, and were awarded the Tyler Prize for Environmental Achievement in 1996 (*Environmental Health Perspectives*, 1996). Willi Dansgaard explains, “The composition of the ice itself tells us about the temperature and atmospheric conditions at the time the ice was formed. So going deep into the ice is like sticking a thermometer backwards in time.” (*Environmental Health Perspectives*, 1996). The idea of examining Earth’s climate history from ice core samples was first proposed in the early 1950’s; followed by the first deep ice core drilling project which took place in 1966 in Greenland (*Environmental Health Perspectives*, 1996). Drilling for glacial ice core samples is a very complex operation, involving a lot of planning, people, and preparation time. First, scientists must construct a camp and excavation site for the drill platform. Then, an electromechanical drill attached to a thin steel cable is commonly used to drill the bore-hole and excavate the ice core sample (Stauffer, 1993). A team working in three shifts can typically drill around 150 meters per week (Stauffer, 1993). Most of the ice core samples are less than 4 inches in diameter and can measure over a mile in length. Furthermore, it takes several years of laboratory analysis to depict the amount of oxygen isotopes, CO_2 levels, and other trace amounts of atmospheric gases, and then date these findings on a linear timeline (*Environmental Health Perspectives*, 1996). The primary interest of these three scientists is to reconstruct the atmospheric CO_2 and methane levels during the last

300 years in order to examine the relationship between global warming and GHG concentrations in the atmosphere. As explained in the *Environmental Health Perspectives* magazine, “This data provides the most dramatic and convincing evidence of global warming tied to human activities.”

Data from ice core samples is still being collected and analyzed in Greenland and Antarctica by a group of multinational scientists. For example, the European Greenland Ice Core Project (GRIP) consists of scientists from Belgium, Denmark, France, Germany, Iceland, Italy, Switzerland, and the United Kingdom (Stauffer, 1993). GRIP recently constructed a detailed model of Earth’s climate from the past several thousand years with a 10% error rate after drilling and examining a 10,000 foot ice core in Greenland (Bulkley, 1994). GRIP’s scientists first had to measure the D/C and A/C electrical properties of this ice core sample in order to examine the calcium and micro-particle concentrations, which measure the amount of atmospheric dust (Stauffer, 1993). Next, they looked at the average amount of ammonium concentrations; which measure the large-scale forest and grassland fires, and volcanic eruptions (Stauffer, 1993). GRIP’s findings showed a very close correlation between climate changes and the levels of CO_2 and methane in the atmosphere.

Scientists have also accurately reconstructed CO_2, methane, and N_2O changes over the past several hundred years by examining the air bubbles found in Antarctica’s ice core samples (Lorius; Jouzel; Raynaud; Weller; McCave; Moore, 1992). Their results show that pre-industrial CO_2 levels averaged 280 parts per million (PPM), compared to over 350 PPM today (Lorius; Jouzel; Raynaud; Weller; McCave; Moore, 1992). This increase in CO_2 can possibly be attributed to human activities; such as fossil fuel usage, deforestation, and landfills. Evidence from these ice core samples also show a linear trend in increased GHG emissions which parallels worldwide population growth. The following graph depicts the rise in CO_2, methane, and N_2O over the past 200 years in relation to population growth since 1800.

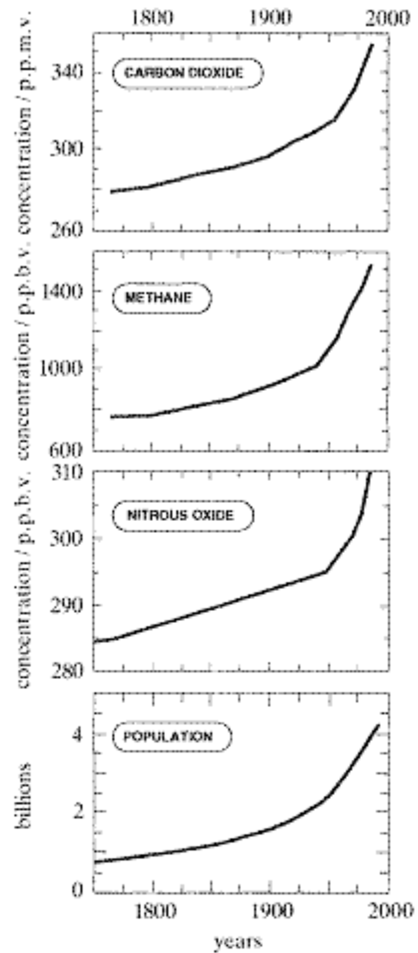

Figure 8. Increase of greenhouse gas concentrations over the ast 200 years from antarctic ice cores. CO_2 (from Oeschger & Siegenthaler 1988), CH_4 (from Pearman *et al.* 1986), N_20 (from Khalil & Rasmussen 1988). The population growth is ncluded for comparison.

The preceding graph clearly shows that population growth is a contributing factor for the rise in GHG emissions which leads to global warming. Thus, if population growth directly correlates with increased GHG emissions, then humans are at least partly responsible for global climate change. Until scientists can better understand Earth's natural changes in its climate cycle, it will be unclear to what degree human action has accelerated global warming.

The evidence gathered from these ice-core samples also show that the Earth naturally goes through cycles of warming and cooling, correlated by CO_2 levels rising and falling. As explained by Jim Motavalli in *The Environmental Magazine*, "There has been a steady 20 percent rise and fall of CO_2 over time from a mean of 240 parts per million (ppm). But today all indicators are going off the scale, and in only one direction. The current concentrations are higher than at any time in the last 400,000 years, according to data accumulated from the Vostok ice core in Antarctica (Motavalli, 2003)". Furthermore, recent data has shown that CO_2 emissions have risen 30% since 1900, which is a 10% increase over Earth's natural variations in the levels of CO_2. Perhaps even more alarming is that until 1999, two gigatons of CO_2 have been released into the atmosphere annually. Furthermore, since 2000, six gigatons have been added to the atmosphere. This is a three-fold increase in CO_2 emissions from 1999 to 2000, which carries devastating consequences in the form of recent extreme weather patterns (Motavalli, 2003).

The past ten years have been the warmest years on record, marked by extreme weather all over the world. Hurricanes since 1990 have been increasingly powerful, resulting in more deaths and greater damage to those who lie in their path. Hurricane Mitch, for example, struck Honduras during October, 1998. It left more than 10,000 Hondurans dead and over two million people homeless (Pearce, 2002). In just a few hours, Mitch dumped a year's worth of rain over Honduras, causing massive flooding and landslides. This was the largest and most powerful storm to ever hit this nation along the coast of Central America, and climatologists say that global warming is at least partially to blame. Hurricane Katrina, the most costly and one of the deadliest hurricanes to ever hit in the United States, is another prime example of extreme weather related to global warming. Hurricane Katrina devastated the lives of millions of people in Louisiana and Mississippi during August, 2005. Its victims are still feeling the effects of Katrina's aftermath today. Over 1,800 people lost their lives; making Katrina the second deadliest hurricane to ever hit the U.S. Katrina was the 3rd strongest (measured by wind speed) hurricane to ever hit the United States, and it left behind more than $80 billion in damages (Pearce, 2002).

Scientists believe that warmer ocean temperatures, resulting from global warming, caused these storms to be intensified. As explained by Dr. Roger Pielke at the Center for Science and Technology Policy Research:

> **Global and tropical atmospheric temperatures near the surface and aloft are increasing, as is water vapor. Tropical oceans have warmed about .6 degrees Celsius over the instrumental record, including about 0.5 degrees Celsius since 1970, and sea levels are rising. Models project these increases to continue well into this century under all plausible scenarios of GHG emissions. It is well known that tropical cyclones form only over warm oceans from which they gain their energy, largely from the latent heat of condensation. Thus, it would not be surprising if a warmer and moister world contained enhanced overall hurricane activity. (Anthes; Corell,; Holland; and Hurrell, 2006)**

Thus, as a result of the oceans getting warmer we have seen a direct correlation in the intensity of hurricanes. The warmer ocean temperatures allow the hurricanes to pick up more precipitation and cause faster wind speeds. In order to prove this phenomenon, Knutson and Tuleya conducted several tests at the National Oceanic and Atmospheric Administration's (NOAA) Geophysical Fluid Dynamics Laboratory. They summarize their findings as:

> **The large-scale thermodynamic boundary conditions for the experiments, specifically sea surface temperatures (SST) and atmospheric profiles of temperature and moisture were based on 80 year linear trends from 1%/yr CO_2 increase experiments from nine different climate model simulations. The projected SST changes in the three tropical cyclone basins studied ranged from +0.8 degrees to +2.4 degrees Celsius. The aggregate results, averaged across all model simulations, indicated a 6% increase in maximum tropical wind speed. While this may appear to be a relatively insignificant increase, nonlinear effects can make even a small increase important in causing damage, because damage is proportional to the cube of the wind speed. (Anthes; Corell,; Holland; and Hurrell, 2006)**

These results indicate that hurricanes could continue to become larger and more powerful as the ocean temperatures rise over the next century.

The changes in Earth's weather patterns as a result of global warming can be seen all over the globe. Many of these changes have never been seen or experienced before, and are leaving behind profound effects on the people and habitat in those areas. For example, areas that have never been prone to hurricanes are now in danger of being caught in the proverbial "eye of the storm". Chouluteca is a case in point. It is located on the Pacific coast of southern Honduras, far from the normal track of Caribbean hurricanes. However, in 1998, Hurricane Mitch washed the small town completely off the landscape, killing over 100 villagers. Linda Rosa Paz was one of Chouluteca's residents. She explains, "When the radio issued storm warnings the night before, no one took notice. Hurricanes never come here" (Pearce, 2002).

Global warming is also making its presence felt in Antarctica and Greenland, Earth's two largest ice masses. Greenland's ice sheet has been melting away for thousands of years; however the rate at which it has been shrinking has doubled since 1996 (Current Science, 2006). According to Eric Rignot at NASA's Jet Propulsion Laboratory, "Greenland's ice melt is now adding enough water to fill Lake Erie each year." Rignot has been studying the movement of glaciers using satellite measurements over the course of several years. He noted in a recent issue of *Current Science* that one glacier under observation had moved very little during the past 60 years, but it is now sliding at a rate of 14 kilometers (9 miles) annually (*Current Science*, 2006). Scientists agree that recent increased glacial movement can be attributed to melt-water seeping under the glaciers, thereby 'greasing' its natural movements. Similar findings have been observed in Antarctica from NASA satellites. Antarctica's ice sheet shrank significantly from 2002 to 2005, and it continues to decrease. Its ice sheet lost 36 cubic miles of ice per year (one cubic mile is equivalent to 264 billion gallons of water) (*Current Science*, 2006). The total melting increased global sea levels by an estimated .05 inch. This increase in sea levels may seem extremely small; however, when considering that the surface of the Earth is over 70% water, an increase in .05 inch is an extremely large amount of water (roughly 9.504 trillion gallons).

Similar examples of glacial melt and glacial disappearance are taking place in almost every part of the world where glaciers have formed. For instance, in Switzerland 84 out of 85 glaciers under observation became smaller in 2006 (Creffier, 2007). Scientists predict that the increasingly hot summers and lack of precipitation in recent years will influence this melting even more. The results of observed glacial melting in 2006 was published by the Swiss Academy of Sciences (SAS), indicating approximately 75% of the melting caused glaciers to shrink by 1 to 30 meters in length (Creffier, 2007). Specific examples published in the SAS report include the 24 kilometer Altetsch glacier, Europe's biggest glacier and part of the United Nation's Educational, Scientific, and Cultural Organization (UNESCO) World Heritage List. According to recent measurements, it receded 114 meters last year (Creffier, 2007). Scientists who survey glaciers commonly measure the 'mass balance' in order to determine the glacier's 'health' (whether it is receding or gaining in mass). The mass balance measurement reflects the balance between the fresh snow the glacier receives from the surrounding area and the ice that melts away in a given year (Creffier, 2007). The melting of these glaciers in Switzerland is cause for concern since glaciers play an important role as water reservoirs for hydro-electric power production, generating as much as half of the country's power needs (Creffier, 2007). The melting can also cause potential hazards, damaging roads and buildings from run-off and landslides. Researchers at the University of Zurich used satellite imagery to determine that glaciers in Switzerland lost 18% of their surface area between 1985 and 2000, at a rate seven times faster than between 1850 and 1973 (Creffier, 2007).

Alaska is also experiencing the effects of global warming at unprecedented levels. The landscape of Alaska is literally being reshaped in ways no one could have ever imagined. Glaciers and sea ice are melting rapidly, permafrost is beginning to thaw permanently, boreal forests are being infested by foreign insect outbreaks, and lakes are beginning to dry up. Gunter Weller, Director of the Center for Global

Change and Arctic System Research at the University of Alaska, explains, “In Alaska, people are more aware of the warming problem because it’s staring you in the face. You can’t deny the evidence because it’s all around you” (Sherwonit, 2004). The native people of Alaska, namely the Inupiat and Athabascan Eskimos, are having to adapt to the ever-present changing environment. Their hunting, fishing, and harvesting activities are now more difficult to sustain, resulting in food shortages. As explained by Willie Goodwin, an Inupiat resident of Kotzebue and special assistant for Alaska’s Western Artic National Parklands, “All our hunting, our whole lifestyle, is being affected. The changes were subtle at first, but now we are very concerned about what we’re seeing” (Sherwonit, 2004). Global warming is dramatically effecting Alaska’s native people who contribute least to the problem, but in many ways are being affected the most.

These changes being felt by the people in Alaska are a result of what scientists call “feedback processes”. These feedback processes are being observed most dramatically in the far Northern and Southern Poles of the Earth, where much of Earth’s ice caps exist. As global warming causes the ice and snow to melt, more areas of land and water are exposed to the sun’s rays. These darker and less reflective (when compared to ice) surfaces absorb greater amounts of solar radiation, causing even greater amounts of warming in the surrounding area. “Basically the warming builds on itself, it has a magnified effect” explains Gunter Weller (Sherwonit, 2004). This process of extreme warming in the Polar regions is also evident when we look at the average annual temperature change globally since 1900. While average annual temperature has increased by 1.75 degrees Fahrenheit globally, the Polar regions have warmed 3.5 to 5 degrees Fahrenheit during the same time frame. The Arctic Climate Impact Assessment (ACIA) is a multinational study involving 300 scientists and indigenous people in the area. Bob Corell, Chairman of the ACIA says, “The Arctic is a preview of the Earth’s future climate shifts. It’s not a question of if; it’s a matter of when” (Sherwonit, 2004). Thus, scientists are viewing areas in the Northern and Southern Poles as Earth’s early warning system for climate change. Many in the scientific community look at these regions as the proverbial canary in the coal mine of atmospheric warming (Sherwonit, 2004).

The melting of these glaciers mentioned in the above examples could start to produce profound results for the people of Europe. If the melting continues at its current rate, Europe may become a much colder place in the near future. Europe lies on the same latitude as Anchorage, Alaska; however it is kept noticeably warmer by the Gulf Stream. John Gribbin, an English science professor, explains, “The Gulf Stream provides western Europe with a third as much warmth at the sun itself, keeping it as much as 18 degrees Fahrenheit warmer than would otherwise be the case” (Motavalli, 2003). The Gulf Stream basically works by moving warm surface water from the Atlantic and Pacific Oceans north until it reaches the Arctic Ocean. Once this warm surface water enters the Arctic’s much colder and denser waters, it begins to cool rapidly. As the warm water is cooled, the denser Arctic water pushes it down to the bottom of the ocean, where the frigid water travels back to the Atlantic and Pacific Ocean, and the process is looped continuously. This process forms steamy, warm surface temperatures which are responsible for keeping Europe’s climate warmer than Alaska’s. However, recent evidence from Britain’s National

Oceanography Center reported in *Nature Magazine* that, “A component of the oceanic current system that drives the Gulf Stream has slowed by 30% since 1992.” (Lemonick, 2005). Another statement from the Goddard Institute for Space Studies explains, “Just one quarter of one percent (.25%) more melt water in the Arctic Ocean could cause the [Gulf Stream] to stop, and Europe would usher in the ‘Big Chill’.” (Motavalli, 2003). Melt water from glaciers combined with warmer surface temperatures may not only shut down the Gulf Stream, but could potentially alter many other oceanic currents as well. This would have compound effects on Earth’s natural ocean and wind currents, possibly resulting in further unpredictable temperature changes all over the globe.

Another example of Earth’s rapidly changing weather patterns can be seen in Tuvalu. Located in the South Pacific, Tuvalu is comprised of nine small coral islands home to an estimated 10,000 people (Pearce, 2002). Recent storm surges, combined with rising sea levels due to thermal expansion of ocean waters, have forced the villagers of Tuvalu to move elsewhere. They recently signed a deal with New Zealand which allows Tuvalu’s villagers to leave their country in fixed numbers each year and resettle in New Zealand. Paani Laupepa of Tuvalu’s Ministry of Natural Resources said, “We have coastal erosion, droughts, and an unusually high level of tropical cyclones. Salt water intrusion into soils has affected our traditional food crops, and now we are seeing flooding of low-lying areas.” (Pearce, 2002).

By looking at these changes happening all over the world it is clear that global warming is not producing gradual changes in our ecosystems, but rather extremely rapid and pronounced shifts in the way our world works. In a recent issue of *Wired*

Magazine (March, 2007), nine landmarks from around the world were identified as being at risk of disappearing in the next 100 years. These locations include: Glacier Bay, Alaska; Glacier National Park, Montana; The Florida Keys, Florida; Tulor Village, Chile; Venice, Italy; Maldives Islands, Sri Lanka; The Great Barrier Reef, Australia; and The Solomon Islands (Greenwald, 2007). It would not only be a disaster for the people living in these places to lose their homes, but it would also be a terrible tragedy for our future generations to be unable to experience these beautiful natural wonders firsthand.

The above examples dictate the far reaching impacts of global warming. People all over the world are experiencing the effects of climate change. The melting glaciers in Antarctica, Alaska, and Greenland are contributing to rising sea levels, which is further influenced by thermal expansion due to warmer weather. We are beginning to see entire ecosystems change in a very short amount of time, causing severe results to all living things in the affected areas. For example, 25% of the entire world's coral reefs have been destroyed in the past 20 years, primarily due to warming sea temperatures (Pearce, 2002). Global warming's effects also contribute to the spreading of disease. In Lima, Peru, a study of over 50,000 children conducted from 1993 to 1998 shows that for every 1 degree Celsius of warming, 3% more children arrive at a local clinic for treatment of diarrhea. In 1998, warm weather doubled the number of children needing treatment (Pearce, 2002). These places which contribute the least to global warming are being impacted the most from flooding, death, and disease associated with Earth's temperature change.

Although human beings are not solely responsible for these dramatic climate changes taking place in nearly all parts of the world, we still share a huge burden of responsibility. Since the Industrial Revolution began in the 19th century, our civilization has become increasingly advanced. We now have the technology available to make better and more effective medicines; allowing us to live longer, healthier lives. Our machines and computers are faster and more advanced, giving us the ability to develop new technological breakthroughs in every facet of our society. The world's cities are growing larger, and our world economies are becoming increasingly inter-related and more global. We now live in a world where the rate of communications and transportation are faster and more reliable than ever before.

All of these advancements in our society have caused the human civilization to grow and expand to all corners of the world. According to the CIA, the world's population is growing at a rate of 1.14%, and recent numbers indicate that there are now over 6.5 billion people living on Earth (www.cia.gov/cia/publications/factbook). China and India are currently two of the fastest growing countries in terms of population growth and economic development. China is home to over 1.3 billion people, while India is not far behind at an estimated 1.1 billion people. However, due to regulations concerning birth control, China's population growth rate is approximately .59%. Comparatively, India's population is growing at 1.38%, which is 2.33 times as fast as China's population growth rate (www.cia.gov/cia/publications/factbook). These rapidly growing populations lead to fast growing economies for these two countries. When we look at China and India, we see virtually the same thing: economic growth, which in turn spurs population growth, which leads to an increased energy demand for each country.

For example, industrial production in India is increasing at a rate of 9.5% per year. Manufacturing output has grown by 10.4% per year, and production of basic metals and alloys rose substantially by 20.7%. Furthermore, the production of transport equipment and parts increased by 16.3%, while the output from mining and utilities increased by 4.3% and 5.6%, respectively (*EIU ViewsWire*, 2006). As India's economy and production continues to grow, so too does its energy demand. This increased energy demand and energy consumption will further contribute to GHG emissions entering our atmosphere.

Production output in China has also been steadily on the rise, primarily resulting from China's cheap labor pool. Companies from all over the world have shifted their production and manufacturing operations to China in search of cheap labor. This increased economic growth is almost directly correlated to China's increased population growth, which is already producing consequences to the environment there. *Science News* recently published an article titled "China's Deserts Expand with Population Growth" in which it explains:

> **The dunes of northern China are expanding at an unprecedented rate. Human activities are primarily responsible for desertification of the arid and semiarid grasslands of the area. The average rate of desert expansion in the region was 3,600 km^2 per year during the 1990's, compared with 1,560 km^2 annually during the late 1950's. The desert's area and the region's population have expanded proportionally during the past 50 years. Nearly 300 million people live in and around the 385,700 km^2 that have become desert since human civilization arose in the region…Intensified cultivation, overgrazing, and clearing of vegetation for fuel are among the contributing activities. (Harder, 2006)**

Thus, increased production combined with an increase in population will drive a growing demand for energy in these and other countries worldwide. As a case in point, the International Energy Agency (IEA) looks at China's growing demand for oil with concern. In the IEA's World Energy Outlook through 2030 it explained, "China's energy security, and that of other big oil consumers, is at risk unless there is government action to slow the growth in consumption of fossil fuels." (Winning, 2006). The report goes on to explain that China is well on its way to overtaking the U.S. as the largest emitter of GHG's by 2010. "The IEA said China would need 15.3 million barrels of oil a day by 2030 if current policies continue, representing an average annual growth rate of 3.4%." (Winning, 2006).

As cities within these countries continue to become more populated we begin to see a trend of rural to urban migration. People have been moving away from farms and small villages and into large urban cities since the late 1800's and early 1900's in many parts of the world. As more jobs and industries become available in larger cities, we find that people tend to move away from rural life to urban life closer to these cities. Urban living usually provides people with more amenities such as electricity, running water, trash disposal, public transportation, etc. However, as cities become more densely populated, greater amounts of energy are required to meet the growing demand. This in-turn leads to a greater amount of energy consumption, due to the increased availability of electricity, natural gas, and gasoline which provides the necessary fuel that drives any large urban city on a daily basis.

China and India are also hubs of rapid growth for the automobile industry. This growth stems from the economic growth mentioned above, as studies have shown that disposable incomes among the middle class in China and India have grown dramatically (Harder, 2006). Thus, more people in these countries have the income available to purchase cars for themselves, which is reflected in the sky-rocketing demand for cars.

In 2006, China's light vehicle sales grew an astonishing 27%, and sales are expected to hit an estimated 7 million new cars and light trucks by the end of this year (Bursa, 2006). China is currently the 3^{rd} largest automobile market after the U.S. (1^{st}) and Japan (2^{nd}). In 2007, new car sales are expected to grow by 12%-15% in China, compared to a less than 1% expected growth for new car sales this year in the U.S. This growth in the auto industry in China is a result of a shift in population growth toward more outlying towns and cities, which helps distribute wealth over a wider area. *J.D. Power and Associates* also reported a 28% drop in the price of an average new car in China from 2000 to 2005 (Bursa, 2006). However, perhaps even more importantly, China's middle class is becoming more wealthy. Statistics gathered from China's Union of National Passenger Car Market Information show that personal savings in China hit a record setting $1.7 trillion at the end of 2005, and an estimated 100 million families each have over $7,500 in savings. Thus, we can see that an increase in wealth combined with a reduction in new car prices results in a huge increase in demand for cars in China (Leggett, 2007).

India is not far behind China in terms of its automotive sales growth. As incomes continue to rise we are beginning to see a spike in demand for cars in India. In 2006, India sold 1.2 million new cars and SUV's. By 2010, that number is expected to jump to over 2 million. By 2015, India is expected to hit 3 million new car sales according to Roland Berger Strategy Consultants (Sedran, 2006). Analysts expect India will emerge as the leader in automotive sales globally somewhere near 2015. Currently, passenger car sales remain at a relatively low 7 cars per 1,000 people. This is mainly due to the lack of widespread road infrastructure in India. The purchasing power is currently there, but the availability is still lacking due to an insufficient transportation department (Rathore and Swarup, 2006). However, some of the world's largest automakers, namely Toyota, GM, and Volkswagen, are already moving to these countries as consumer demand continues to rise.

Every new car sold will become a contributing factor to the problem of global warming. China is already beginning to see the results of the greater number of new cars on its roads. Oil consumption has risen dramatically as a result of this increase. At current growth rates, China's annual vehicle demand will reach 18.9 million units by 2020, accounting for 60% of the nation's total consumption of oil (*The Engineer*, 2007). In response to this growing problem, China has already implemented a 20% 'consumption tax' on cars that have poor gas mileage, and on any car whose engine is larger than 2.0 litres (*The Engineer*, 2007). Toyota, the current market leader in Hybrid-Car technology, currently has plans to increase production of its Hybrid cars in China in response to this issue (Leggett, 2007).

The transportation industry in the United States is another leading cause of GHG emissions contributing to global warming. As the world's largest auto market (in terms of sales), there are now more cars in the U.S. than there are registered drivers. Recent studies show that for every person in the U.S., there are 1.2 cars on the road (Fairclough, 2006). Of all of the cars on the road today, SUV's and trucks are among the least efficient in terms of fuel economy. Despite recent increases in fuel prices at the pump, the popularity and sales of SUV/trucks is on the rise. An estimated 38% of automobiles on the road in the U.S. are classified under the SUV/Truck category, according to the Department of Transportation. Due to their increased size and weight, more powerful engines are required for this category of autos, resulting in lower fuel economy when compared to passenger cars. This lower fuel economy equates to more GHG emissions per mile driven when compared to more fuel efficient vehicles. Furthermore, the mass- transit system in many states across the U.S. is lacking, especially when compared to Europe. Trains and subway systems are widely used as a means of transportation in Europe which contributes to lower GHG emissions per capita.

If our state and federal governments worked together to implement a country-wide mass transit system, similar to Europe's, our GHG emissions should drop substantially. Considering we are the world's leader in GHG emissions, emitting 25% of the GHG emissions per year worldwide, and that the U.S. only contains 4% of the world's population (*Current Science*, 2006); it is clear that as a nation we need to change our lifestyle. Thus, if we started reducing the number of cars and trucks on the road and made a shift to driving more fuel-efficient vehicles, we should see a drop in our nation-wide emissions.

Politics and economics also contribute to the problem of rising GHG emissions, especially in the United States. For many years global warming has been an issue widely discussed by Senators, Congressmen, and Governors, and the issue seems to have made little progress when it comes to government action. For example, in 1992 Representative Henry A. Waxman proposed legislation aimed at reducing GHG emissions in the U.S. (Reppert, 2006), however, Congress still remains gridlocked on establishing some sort of national policy regulating this issue. On June 20, 2006; Waxman and twelve co-sponsors introduced the “Safe Climate Act” to Congress. Under this act, the U.S. would cap GHG emissions in 2010 and begin reducing them by 2% per year until 2020 (Reppert, 2006), which would further reduce emissions by 20%. Furthermore, after 2020, emissions would be required to fall by 5% per year as more advanced technologies become more widely available (Reppert, 2006). Representative Waxman states, “Global warming is the greatest environmental challenge of our time, and we have a short window in which to act to prevent profound changes in our climate system. Unless we seize the opportunity to act now, our legacy to our children and grandchildren will be an unstable and dangerous planet.” (Reppert, 2006).

Other politicians have proposed similar acts to Congress with little success. For instance, Senators James Jeffords and Barbara Boxer introduced the ‘Global Warming Pollution Reduction Act’ on July 20, 2006. Under this act, the U.S. would incrementally reduce its GHG emissions by 80% by 2050 (Reppert, 2006).The Union of Concerned Scientists (UCS), an environmental group based out of Cambridge, Massachusetts, urged its members to contact their local Senators and Representatives to support these Jeffords-Boxer and Waxman bills (Reppert, 2006). In response to this act, Senator Jeffords recently said on the Senate Floor:

> **“Some will say this bill imposes requirements that ask too much of industry. Some will say that this bill contains requirements that we cannot easily meet. I say first of all that the costs of inaction vastly**

> **outweigh the costs of action, and that we have a responsibility to future generations not to leave Earth far worse off than we found it—with a fundamentally altered climate system."** (Reppert, 2006)

Despite their efforts, many environmental groups (including the UCS) do not expect this act to pass the current Congress.

Many environmental groups are beginning to take action in response to government inaction concerning climate change policies. The Sierra Club, for example, is a large national environmental group which recently made global warming and alternative energy policies one of its top priorities. The organization is expected to create more campaigns aimed at adding more efficient and environmentally friendly energy policies, as well as reducing the number of refineries and refinery capacity (Leiter, 2005). They also plan on lobbying for more energy efficient technology being used at the state and local levels, such as purchasing more hybrid vehicles by municipalities (Leiter, 2005).

Far better progress is being made to reduce emissions at the local governmental level however. The Regional Greenhouse Gas Initiative, for instance, was passed on August 15, 2006. This was an initiative formed by several northeastern states (Connecticut, Delaware, Maryland, Maine, New Hampshire, New Jersey, New York, and Vermont) to reduce GHG emissions from their power plants by implementing a 'cap-and-trade' emissions program (Reppert, 2006). Under a cap-and-trade system, each participating state will be given an emissions level cap (usually set on a per capita basis) which limits the maximum amount of emissions that state can produce per year. However, states are allowed to buy and trade unused emissions from other states that emit less than their established emissions level. For example, if Delaware's emissions cap is set at 50 million tons of GHG emissions/year and the state only emits 40 million tons of GHG's/year, then it would have an excess of 10 million tons of GHG emissions for that year. It could then sell or trade those excess (or "unused") emissions to another state which plans to emit more GHG than its cap allows. Thus, an entire new form of market economy would be created under this approach, which could potentially generate additional revenue that, in turn, could be invested in alternative fuels, or emission reduction technology for each state.

Steps towards emissions reductions are already taking effect overseas due to government support. In London, for example, more efficient power systems combined with transportation reforms are being implemented. Allan Jones was brought in to head London's Climate Change Agency after working in Woking, a suburb in England. Jones reduced Woking's energy use by 48% since 1990 (a total reduction of 5.4 million pounds of CO_2) by a using combined heat and power (CHP) cogeneration system and solar energy technology ("Climate for Change", 2005). London plans to scale Jones' work in Woking to London in order to reduce the city's emissions by 20% by 2020 ("Climate for Change", 2005). In 2003, the city of London also began charging a $9 "congestion charge" for all vehicles entering the city, which resulted in a 30% reduction in traffic delays ("Climate for Change", 2005). The city now reports increased bus and subway use after implementing its "congestion charge" fee. The Chinese government also plans to reduce its GHG emissions by 2010 by targeting a 20% reduction in energy consumption (Winning, 2006). These are only a few examples of the importance of government support when dealing with climate change policies.

Businesses carry a large burden of responsibility when dealing with the issue of global warming. Industry emissions are one of the leading causes of GHG emissions in the United States. However, to many businesses the economics of reducing GHG emissions isn't justified, especially when looking at the bottom line. Since the number one priority for large corporations is to "maximize shareholder value" (namely to increase earnings, or ROI), many companies aren't willing to spend the necessary investments in time, money, and policies to reduce their emissions. Many businesses agree with the Bush administration's view that mandatory emissions reductions will, "Cripple the U.S. economy while relying on questionable science" ("*Global Warming*", 2006).

However, many businesses are beginning to see that it makes good business sense to reduce their GHG emissions. Daianna Rincones is the Business Support and Development Manager for Business in the Environment, a group based in the U.K. which helps companies work towards environmentally sustainable development as a strategic, mainstream business issue ("*Global Warming*", 2006). She explains, "There are some outstanding companies in the U.K., Europe, and the U.S.; such as Philips Electronics, Toyota, and ABB, that gain maximum benefit from their activities because they understand the link to efficiency, cost savings, innovation, and competitive advantage" (*"Global Warming"*, 2006). Thus, through environmentally friendly practices many businesses could positively affect their bottom line earnings. As a case in point, LKAB, a Swedish based mining company, recently replaced 15,000 electric motors with high-efficiency motors in all of its mines and processing plants. As a result, its energy costs per year have dropped substantially ("*Global*

Warming", 2006). John Mukka, LKAB's energy expert, explains, "By changing to high-efficiency motors, we've knocked several hundred thousand dollars off our annual energy bill. A high-efficiency motor might cost more, but at the end of the day the procurement price is only one percent of a motor's life-cycle cost; which makes for an enormous savings" ("*Global Warming"*, 2006). Other companies should begin to view these examples, such as LKAB, as a new way to look at investing in environmentally sound business practices. Although investing in GHG reduction technologies may cost more in the short term, annual energy savings could potentially show a positive return in the long run. This also makes good business sense from a marketing standpoint. By investing in environmentally friendly practices, businesses can market their products accordingly. British Petroleum (BP), the second largest oil producer in the world, has already begun using this marketing tactic. Nearly all of BP's current television ad's focus on their "green energy practices", such as their lowered emissions practices and investments in alternative fuels. In a 2005 study, BP reportedly lowered its total emissions from 107 million tons of GHGs in 1998 to 91.6 million tons in 2004, a 14% decrease over the seven year period ("*Global Warming"*, 2006). As stated in BP's annual report:

> **"We expect future progress to come from many small-scale projects. To encourage these, we launched a five-year, $350 million program in 2004 to develop technologies and processes that will reduce GHG emissions, with a goal of avoiding (reducing) one million tons each year. In 2004, $50 million was allocated to around 100 such projects, with the remaining $300 million to be spent over the next four years." (**"*Global Warming,* 2006)

For a company like BP, $350 million is a relatively small investment in reducing GHG emissions considering its net income exceeded $22 billion in 2006. However, the impact of its emissions reduction practices not only helps lower GHG's, but it is also the cornerstone of BP's successful marketing campaign. Other companies should begin to re-examine how investing in emission reduction technology could not only positively affect their bottom line in both the short and long term, but also potentially attract new customers who are concerned with the issue of global warming.

It is important to note that there are several "natural" causes of global warming which humans are not directly responsible for. Events in nature, such as volcanic eruptions and forest fires, release large amounts of methane gas and CO_2 into the atmosphere every year. Forest fires are especially important when discussing the issue of global warming and climate change because forests act as "carbon sinks" by sucking up excess CO_2. Forests, and trees specifically, absorb carbon dioxide in the air and release oxygen during the process of photosynthesis. Thus, the more forests we have in the world, the lower overall global CO_2 will be released into the atmosphere. A recent study conducted by the American Museum of Natural History showed that in the Amazon Basin alone, rainforests could be absorbing over one billion tons of carbon dioxide each year (Laurance, 1999). That same study also showed an interesting correlation between increased levels of CO_2 and the rate of tree growth in the Amazon rainforests. The scientists conducting these studies noticed that the trees are beginning to grow larger per acre, and at a faster rate. One research member, Oliver Phillips, explains, "We found that the total mass of living trees in each acre of rainforest at our sites has increased by an average of 17 metric tons

(37,000 pounds) since the beginning of our study." (Laurance, 1999). Phillips and his team have been studying over 100,000 trees in the Amazon rainforest since 1968. The research team believes this accelerated tree growth is a direct response to the increased levels of CO_2 currently found in our atmosphere.

Unfortunately, we may be losing many of these "carbon sinks" as forest fires (both natural and man-made) and deforestation continue to increase in many parts of the world. An estimated 40 million acres of tropical rainforests are cleared and burned each year, which is equivalent to over seventy football fields a minute (Laurance, 1999). An additional 15 million acres are being logged each year according to current estimates. The combined result is the source of 25% of the world's GHG emissions (Laurance, 1999). Brazil and Madagascar are two places in the world where the problem of deforestation is on the rise.

Although Brazil has already taken steps to reduce its GHG emissions by replacing gasoline with ethanol for cars, its emissions continue to rise due to increased deforestation. Brazil is only responsible for 3% of the world's GHG emissions, but 25% of Brazil's emissions come from tropical deforestation (Campos; Rousseff; and Silva, 2004). GHG emissions grew 5%, from 979 million tons to 1.03 billion tons, between 1990 and 1994 in Brazil and continue to rise. For example, in 2002 deforestation grew by 28%; and in 2003 the problem increased by an additional 2% (Campos; Rousseff; and Silva, 2004). Many environmental organizations from all over the world are beginning to take note of this growing problem. Brazil's President, Luiz Inacio da Silva, is concerned, and has recently announced that curbing deforestation will be one of his country's main commitments. In 2005, 23,750 square kilometers of rainforest were cut down; and in 2006 an estimated 30,000 square kilometers (an area the size of Belgium) were destroyed (Campos; Rousseff; and Silva, 2004). According to Stephan Schwartzman, a senior scientist at the Environmental Defense Fund in Washington D.C., “The burning of the Amazon is not over. It’s getting worse.” (*Amazon’s Aflame*, 1997). Furthermore, a multinational team of researchers believe that another 15,000 square miles of rainforest are eradicated each year in Brazil, which is double the amount of previous estimates (Couzin, 1999). Researchers have concluded that since 1972, more than 200,000 square miles of the Amazon have been cleared from either logging, forest fires, or a combination of the two (Couzin, 1999). The burning of trees produces 220 million tons of CO_2 per year, making Brazil the world’s sixth largest producer of CO2 emissions (*Burning Rainforests*, 2004). Not only does this add to the problem of global warming, but the Amazon is also home to 90% of the world’s plant and animal species (*Amazon’s Aflame*, 1997). Thus, as the Amazon continues to shrink, we as humans are not the only species whose habitat is being destroyed.

Madagascar is another area where deforestation is taking place almost year-round. The primary cause of deforestation in Madagascar stems from the Tantsaha, the native farmers and herders of this country. The Tantsaha constantly use fire as a necessity in their everyday life, for purposes ranging from pasture renewal to crop-field preparation (Kull, 2002). Every year, these fires consume up to half of Madagascar’s central grasslands, and thousands of square kilometers of its rainforests (Kull, 2002). The French colonial administration, Madagascar’s government, and outside conservation groups have attempted to limit or stop the Tantsaha’s widespread, and sometimes uncontrolled, burning since the early 1900's. Unfortunately, state disunity combined with a lack of money and adequate staffing has rendered Madagascar all but powerless in controlling this problem. According to Madagascar's Forest Service, a single agent can be responsible for monitoring 800,000 hectares of park area (Kull, 2002). Thus, the Tantsaha are essentially free to burn almost wherever they please, anytime they please. These herders and farmers view fire as an important part of their livelihood. For example, fire can be used as a tool for extensive range and pasture management, as well as a means for pest control. Small "cleaning" fires are used around crop-fields and homes to help reduce rat, tick, mosquito, and locust populations (Kull, 2002). These are only a few examples of how fire and large scale burning are an important tool for the indigenous people of Madagascar. For thousands of years, people from all over the world have used fire as a means for survival. However, just as these fires are helping people such as the Tantsaha survive, the problem of increased deforestation is contributing to global warming which affects everyone in all parts of the world. This serves as a paradox demonstrating how one issue may be critical for a group of people's survival, while at the same time harming the environment for the rest of the world.

Another important natural cause contributing to global warming can be found in Siberia and Indonesia. These two countries contain a majority of the world's peat, which is soil composed of the dead and decayed remains of vegetation and is thought to be the first stage in the formation of coal (Current Science, 2005). However, when peat begins to melt or burn, it releases large amounts of methane gas into the atmosphere, which is a greenhouse gas 20 times more potent than CO_2 (Current

Science, 2005). In Siberia, scientists recently reported that a one-million-square-kilometer (386,000-square-mile) area of permafrost had suddenly begun thawing. This melting area is the world's largest peat bog which has remained frozen for an estimated 11,000 years (Current Science, 2005). Sergei Kirpotin, a botanist at Tomsk State University, explains, "In just the last three or four years it has begun to melt dramatically." (Current Science, 2005). This peat bog holds an estimated 70 billion tons of methane, which would greatly contribute to the growing problem of GHG emissions worldwide. According to David Viner, a scientist at the Climatic Research Unit at the University of East Anglia in England, "The release of that gas into the air could accelerate global warming. This is a big deal because you can't put the permafrost back when it's gone." (Current Science, 2005).

Indonesia is also home to some of the world's largest stores of peat. Unlike Siberia, where the peat is frozen under the permafrost, Indonesia contains tropical peat found in large patches of earth exposed at the ground level. These tropical peat bogs are among the planet's largest stores of CO_2 and methane (New Scientist, 2002). A team of scientists from Britain, Germany, and Indonesia explained that when Indonesia's forests burned in 1997, the burning peat underneath the trees released an estimated 2.6 billion tons of carbon into the atmosphere, which was equivalent to 40% of global emissions from fossil fuels that year (New Scientist, 2002). Furthermore, researchers believe that was the primary cause of the largest annual increase in CO_2 levels in 40 years, releasing an estimated 6 billion tons of additional CO_2 into the atmosphere (New Scientist, 2002). Scientists believe the peat bogs in Indonesia are up to 20 meters deep, and contain up to 50 billion tons of CO_2. That's equivalent to eight years of fossil fuel emissions (New Scientist, 2002). David Schimel of the National Center for Atmospheric Research in Boulder, Colorado explains, “It could all be released into the atmosphere over the coming century, adding to global warming. This reveals how catastrophic events affecting small areas can have a huge impact on the global carbon balance.” (New Scientist, 2002).

The final section of this thesis discusses the possible solutions for reducing GHG emissions by examining viable alternative energy sources. As worldwide GHG emissions continue to increase each year, it is clear that we must begin to lower our energy dependence of fossil fuels. According to recent estimates, the world’s oil supply will be exhausted in an estimated 60 years, while the world’s coal supply will be depleted in 200 to 300 years (Hodgson; Marignac, 2001). Furthermore, if we continue to use these fossil fuels as our primary energy source, Earth’s climate would be drastically altered. Joseph Romm, founder and executive director of the Center for Energy and Climate Solutions, explains, “It’s not too late, but we must move away from fossil fuels…or ruin the planet for the next 50 generations.” (David, 2006). Romm advocates a massive investment in alternative energy and national move towards current alternative technologies in order to reverse the U.S.’s consumption of fossil fuels by 2020 (David, 2006). Caltech professor Nathan Lewis states, “This is about risk management. The lifetime of greenhouse gasses is thousands of years. We are ticking closer to the point where the world is not ever going to be the same. We need to do the things we know how to do now, starting today.” (David, 2006). Many people in the alternative energy business, such as Kelly Fletcher, Sustainable Energy Advanced Technology Leader at GE Global Research, agree that government policy support is critical to successful implementation of these alternative sources. Government incentives and subsidies would not only rapidly accelerate the alternative energy market, but it would also help create now job opportunities as new businesses, such as bio-fuel plants and wind farms, begin to emerge. A recent poll conducted by *Electronic Design Magazine* showed 81% of its reader's advocated added government spending for alternative energy programs in the United States (David, 2006). It is clear; however, that no single alternative energy source will suffice when moving away from fossil fuels, we must use a combination of alternatives for this shift to be successful.

The first multinational governmental attempt to reduce GHG emissions started when 150 countries signed the Kyoto Protocol in Kyoto, Japan in December, 1997. The origin of the Kyoto Protocol dates back to the 1992 U.N. Conference on the Environment and Development (also known as the "Earth Summit" meeting) held in Rio de Janeiro, Brazil in 1992 (Schmidt, 2000). The attending member nations at this meeting formed the United Nations Framework Convention on Climate Change (UNFCCC) with an ultimate goal of "stabilizing greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous interference with Earth's climate." (Greene, 2000). When the UNFCCC members meet they establish various workshops, each with its own specific goal for reducing climate change in areas such as transportation, industry, agriculture, etc. (Greene, 2000). By May 2000, 184 countries had ratified the UNFCCC in order to create a unified policy of reducing GHG concentrations in our atmosphere. As a follow up to the original UNFCCC, the Kyoto Protocol was drafted at the Third Conference of the Parties (COP3) to the

UNFCCC in December, 1997 (Schmidt, 2000). This marked the first international attempt to set binding limits on GHG emissions for participating countries. Under the Kyoto Protocol, countries are classified as either ‘developed’ (such as the U.S.) or ‘developing’, and each member nation has specific emissions limits per year. However, emissions limitations are not placed on developing countries, but rather a system called the Clean Development Mechanism (CDM) is used instead. The CDM allows developed nations to earn emissions reduction credits by investing in environmentally friendly projects which reduce GHG emissions in developing countries (Wiener, 2004). This CDM system is part of a larger emissions trading market created by the Kyoto Protocol, where member nations can buy and sell excess (or unused) emissions. For example, a nation whose emissions fall below treaty limits can sell or trade its unused emissions to another nation whose emissions exceed treaty limitations. The CDM system further adds to this new ‘emissions market’ by allowing developed nations to earn emission credits (essentially raising a nation’s emissions limitations) by funding projects for emissions reduction in developing countries (Wiener, 2004). Currently the only two countries in the United Nation who haven’t ratified the Kyoto Protocol are China and the United States.

There are many critics of the Kyoto Protocol’s policy, especially in the United States. First, many critics explain that the developing nations who are not bound by emissions limitations are on track to becoming the largest emitters of GHG’s within the next 15 years from increased lower-technology industrialization, added deforestation, and a growing transportation industry (Schmidt, 2000). As a result, the developed countries are going to suffer economically from these emissions limitations, while developing countries will be the only ones who benefit. Another criticism based around the emissions trading system established by Kyoto claims that this system will simply move emissions from one place to another. For example, if a developed country wants to keep increasing its emissions from one year to the next, it can simply keep investing in emission reduction projects in developing countries to gain more emission credits, as well as buy unused emissions from other developed countries. Thus, a country can keep raising its emissions based on how deep it wants to dig into its pocket-book. There is also a controversy about how the Kyoto Protocol establishes its emissions limitations. Many critics view these limitations as being set unfairly and arbitrarily by simply reducing emissions to 1990 levels without reasonable analysis (Wiener, 2004). As a result, some nations would have to bear an un-proportionately large amount of these emissions reductions. For example, if the United States were to ratify the Kyoto Protocol, it would have to reduce 50% to 80% of worldwide emissions due to its already large and fast growing emissions levels (the U.S. currently emits 25% of the world's GHGs) (Wiener, 2004). Furthermore, when viewed from a "cost vs. reward" approach the Kyoto Protocol would place large economic burdens on countries such as the United States. According to Representative Joseph Knollenberg (R. Michigan), "Implementing the Kyoto Protocol would result in the loss of 2.4 million jobs and reduce the average annual income by nearly $2,700." (Schmidt, 2000). Several other economic models show the cost of meeting Kyoto targets for the U.S. would result in a net loss of 1% to 3% of total GDP per year (Wiener, 2004). Similarly, in China the cost of implementation would reduce that country's GDP by 4% to 9% per year (Wiener, 2004). These costs clearly outweigh the benefits when examined from a purely economic standpoint. On the other hand, Dan Lashof, a senior scientist with the Natural Resources Defense Council in Washington, D.C., states, “These kinds of cost estimates are based on economic models that are heavily dependant upon input parameters.” (Schmidt, 2000). For example, another study found in the World Wildlife Fund’s August, 1999 report entitled, *America’s Global Warming Solutions* found that 900,000 new jobs would be created along an with annual savings of $400 per household would result if the U.S. ratified the Kyoto Protocol (Schmidt, 2000). However, when we begin to factor in the permanent impact on our environment from refusing to reducing emissions, a quote from Senator Jeffords comes to mind, “I say first of all that the costs of inaction vastly outweigh the costs of action.” (Reppert, 2006).

The business behind alternative energy is beginning to take off as many investors are putting their money into alternative energy companies. After President Bush announced in this year’s State of The Union speech that today’s oil consumption is not sustainable and has “contributed to climate change”; many people began investing in alternative-fuel stocks. High gas prices have also spurred interest from investors in this emerging market sector, which now receives $612 million in venture capital funding (Polyak, 2007). This is a 400% increase when compared to last year’s investments in the alternative energy sector. According to *Thompson Financial*, “This is an area that’s growing in sales at double digits a year and will continue to grow at that rate for at least another 10 years. The numbers are unequaled by any other industry.” (Polyak, 2007). In many areas of business, rapid growth often brings rapid innovations. Thus, as we can see from these figures the alternative energy sector is a promising industry for future growth and new developments.

One viable and fairly widely used alternative energy source is nuclear power. Currently, 17% of the world's electricity is produced by 438 nuclear power plants (Hodgson; Marignac, 2001). In the U.S., roughly 20% of our electricity is generated from nuclear power, which reduces our nation's GHG emissions by en estimated 6% (Hodgson; Marignac, 2001). Nuclear power is most widely used in Europe, producing 80% of France's electricity, and 50% of Western Europe's power needs (Hodgson; Marignac, 2001). France estimates that its GHG emissions have been reduced by 50% as a result of using nuclear power as its primary energy source (Hodgson; Marignac, 2001). Thus, nuclear power plants have the capacity to supply highly populated countries, such as France, with very clean energy. This type of energy produces almost no greenhouse gases, which could further help many industrialized counties reduce their annual emissions. Also, aside from common belief, nuclear reactors are very safe and efficient when operated correctly. Cases such as Chernobyl and Five Mile Island have placed misconceptions concerning the safety of nuclear reactors, when in fact these accidents could have been easily prevented had it not been for human error and carelessness (Hodgson; Marignac, 2001). Dr. Rosen, the former Head of Nuclear Safety at the U.N. stated shortly after the Chernobyl accident, "Even if there was this type of accident every year, I would still consider nuclear power to be a valid source of energy." (Hodgson; Marignac, 2001). Modern nuclear power technology is continually being improved, which helps reduce the risk of another serious accident. Peter Hodgson is a nuclear physicist at Oxford University who has been active in this field since 1948. He widely advocates increased power production from nuclear reactors, but he believes reactors should be required to operate under the supervision of the International Atomic Energy Agency (IAEA) (Hodgson; Marignac, 2001). He explains that strict operating standards will greatly reduce the probability of a future incident.

Although most nuclear reactors in the world have an excellent safety record, there are many disadvantages that must be examined as well. One major drawback of nuclear power is the byproduct of radioactive nuclear waste, which is very costly to store and dispose of. This radioactive waste remains dangerous for thousands of years, which adds to the seriousness of the risks associated with nuclear power. Technology is currently available (and widely used in some countries, such as France and the U.S.) to reprocess this nuclear waste to further extract small amounts of useful fuel. However this also bears greater risks if these reprocessing plants are not operated correctly. For example, a reprocessing plant in West Valley, New York left 600,000 gallons of radioactive waste in steel tanks which started to decay in 2001 (McGowan, 2001). The federal government spent several million dollars cleaning this site up, which prevented contamination in the area. This example shows how serious and costly nuclear waste disposal can be. Furthermore, the problem of nuclear waste management increases as more nuclear reactors are built. More reactors would also increase the risk of an accident, such as a meltdown, occurring. Although these risks are currently very small, they begin to compound with every newly built reactor. Also, the severity of an accident increases based on population density of the surrounding area. In a highly populated state such as California, current opinion polls indicate that nuclear power is considered too risky (Hodgson; Marignac, 2001. Thus, until we find a more effective means for disposing of nuclear waste we should continue to examine other viable sources of alternative energy.

A new technology recently emerged in China which would use helium-3 (3HE) to power nuclear fission reactors. Helium-3 is a stable isotope which was first discovered in moon rocks brought back from the Apollo missions (Carmichael; Liu, 2007). Scientists believe helium-3 is a byproduct of “solar winds” which bounce off Earth’s magnetic field. However, since the moon has no magnetic field, the lunar surface has been soaking up helium-3 for billions of years (Carmichael; Liu, 2007). According to Gerald Kulcinski, Director of the Fusion Technology Institute at the University of Wisconsin at Madison, “If you dig [helium-3] up and put it into a fusion reactor you would get ordinary helium-4 (as in balloons), ordinary hydrogen (as in H_2O), and an abundance of radioactive free energy. A mere 40 tons would be roughly enough to serve America’s electrical needs for a year.” (Carmichael; Liu, 2007). China has plans for a lunar program specifically designed to find significant deposits of helium-3, and learn how it is distributed on the lunar surface. However, China’s engineers are still attempting to develop a working, large-scale reactor using 3He (Carmichael; Liu, 2007). If this technology is deemed economically viable as well as practical, this could potentially be a huge breakthrough for a source of clean energy worldwide.

Wind power is beginning to grow in the alternative energy sector because it produces very clean, renewable, and cost efficient energy. Unlike nuclear, wind energy produces no harmful byproducts (aside from the reportedly “annoying” noise produced by the wind turbines). It is also the most economical form of alternative energy, costing 4 to 6 cents per kilowatt hour (Polyak, 2007). Spain currently uses wind power to generate 5% of its total annual energy (Bigham, 2007), and many other countries are beginning to look at wind power as an attractive alternative to coal. One company here in Texas is planning on creating large scale wind farms for power production. W.E.S.T., which stands for Wind Energy Systems Technology, was formed in 2004 by two investors from Houston, Texas (Geoghegan, 2007). The company plans on using high tech wind turbine technology to create wind farms 10 miles off the shore of Galveston. These state of the art turbines are equipped with wind-monitoring equipment as well as radar for tracking migratory birds. These wind turbines sit on top of decommissioned oil platforms, which have been outfitted with additional hydraulic lifts so the turbines can be lowered in the event of a hurricane (Geoghegan, 2007). After a Stanford University study identified the Louisiana-Texas coastline as one of the best places in the U.S. for wind power, W.E.S.T. bought an 18 square mile site offshore near Galveston. According to W.E.S.T., "We found that this area has exceptionally high average wind speeds which are strongest during the hottest hours of the day, when demand for power is at its peak and electricity prices are highest." (Geoghegan, 2007). Currently, W.E.S.T. plans on building 50 wind turbines by 2008, which would produce an estimated 150 megawatts of power per year. They also plan on building an additional 50 turbines by 2010 if demand begins to increase (Geoghegan, 2007). W.E.S.T. also has plans to set up a wind farm in Utila, an island off the coast of Honduras by 2010. Superior Renewable Energy is an Australian investment firm which plans to follow in W.E.S.T's footsteps. It plans on building wind farms off the coast of Padre Island and Corpus Christi, Texas, within the next several years (Geoghegan, 2007). The main disadvantage of wind generated energy, according to these companies, is the high cost of running transmission lines between generators and end-users (Geoghegan, 2007).

Solar energy is another source of clean, safe, and renewable energy. Like the rest of the alternative energy market, investments in solar technology are beginning to grow. For example, SunPower, a company which makes high efficiency solar-power cells, has recently seen a 166% increase in earnings compared to last year (Konrad, 2007). Investors believe high gas prices combined with a move towards more renewable sources of energy are the primary cause. Although solar power currently costs nearly twice as much as conventional (coal) power, new technologies from increased investments have driven its cost down. For example, in 1990 the cost of a solar kilowatt-hour was 47 cents. Today, due to more efficient photovoltaic solar cells, the cost of a solar kilowatt-hour has dropped to 21 cents (Konrad, 2007). The solar industry is also benefiting from an increasing number of government subsidies. Businesses which use solar power currently receive a 30% tax credit, and both local and state governments are beginning to offer incentives for solar use as well (Konrad, 2007). Current solar photovoltaic cell technology enables the roof, walls, and windows of a building to trap the heat from the sun and transfer it into electricity (Leggett, 2000). Also, solar power can be stored in high-efficiency batteries and fuel cells during stormy or cloudy weather which further adds to the reliability of this technology and makes it less weather dependent (Leggett, 2000). Depending on energy use, some homes using solar power can actually generate more energy than they use. This unused power can then be sold back to the power grid, essentially making the home a small power plant (Leggett, 2007).

Another alternative energy sector experiencing rapid growth is ethanol production. Most ethanol is made from either corn (most of U.S. produced ethanol) or sugarcane (mainly found in Brazil's ethanol production). Cellulosic ethanol is a new technology which has recently emerged that would produce ethanol from a mixture of switch grass, wood, and various agricultural and forestry wastes (Shieber, 2007). This would help eliminate ethanol production's dependency for agricultural crops like corn and sugarcane, which have experienced rapid market changes since the ethanol market emerged. For example, in the past five years the percentage of the U.S. corn crop devoted to ethanol has risen by 17%, or 8.6 million acres of farmland (The Wall Street Journal, 2007). This has caused the price of corn to rise by 80% in 2006, which has profound impacts on other industries. Cattle, poultry, and hog farmers now have to raise their costs in order to pay for the increase in feed corn, which in turn makes these industries less competitive when compared to foreign competitors (The Wall Street Journal, 2007). Also, in Mexico the price of corn tortillas (which is a dietary staple) has increased by 30%, which has resulted in widespread protests over price controls. China has now decided to ban construction of ethanol plants in its country because of the potential threat it may pose to the nation's food supply (The Wall Street Journal, 2007).

Many governments are actively supporting ethanol production because it is a renewable fuel source. In the U.S., ethanol receives a 51 cent/gallon tax credit and a 54 cent/gallon tariff on imported ethanol in order to boost domestic production (The

Wall Street Journal, 2007). Furthermore, President Bush has recently approved $2 billion in government loans to help promote the ethanol industry and issued a federal mandate for the oil industry to use at least 7.5 billion gallons of ethanol by 2012 (Polyak, 2007). Federal and state subsidies for ethanol also increased to $6 billion last year, which is equivalent to half of ethanol's wholesale market price for the entire year of 2006 (The Wall Street Journal, 2007). The European Union is also advocating more ethanol use by issuing a plan for ethanol to be used for 10% of the transportation industry's fuel needs (Polyak, 2007). This increased governmental support for the ethanol industry has helped create new alternative energy companies, which in turn helps the entire U.S. economy by creating new jobs. For example, Mascoma Corp. recently received $14.8 million in grants from the New York State Department of Agriculture and the New York State Energy Research and Development Authority to open an ethanol processing plant in Rochester, New York. Celunol Corp. and Iogen Corp. are also newly formed companies in the U.S. and are currently researching cellulosic-ethanol production. They currently have processing plants in Massachusetts and Louisiana which are testing new raw materials and processing techniques for cellulosic ethanol. Furthermore, the entire town of Reynolds, Indiana (population 547) was primarily a agricultural community until Indiana's Governor, Mitch Daniels, transformed it into what he calls "Biotown, USA" (Gross, 2007). He wants to make ethanol production the town's primary business by building an ethanol plant which will buy the corn and soybeans produced from local farmers. Demand for ethanol has even begun to outpace supply, as 330,000 barrels/day are being produced in the U.S., with a demand of 391,000 barrels/day

(Zwirn, 2007). In 2006, 4.9 billion gallons of ethanol were produced in the U.S., and that figure is expected to double within the next two years (Zwirn, 2007). Currently, there are 110 ethanol refineries in the U.S., however an additional 79 are under construction to help meet demand. After these additional refineries are completed, the annual ethanol production in the U.S. is expected to jump to 11.3 billion gallons (Zwirn, 2007). Consumption is also expected to increase by 25% in 2007 to 6.5 billion gallons/year. Laws such as the Renewable Fuels Standard Act, which requires states to use ethanol blending in gasoline, continue to help drive the demand and consumption of ethanol even higher (Zwirn, 2007). Emerging technology, such as genetic modification, is also being researched to help increase ethanol production in order to meet this growing demand. Average corn yields 400 gallons of ethanol per acre, however genetically modified corn increases this yield to an estimated 750 gallons per acre (Khosla, 2007). According to E3, a newly formed ethanol production company, future research in cellulosic ethanol production could promise yields of 2,700 gallons/acre by 2030 (Khosla, 2007).

Brazil is perhaps the best example of this growing ethanol industry. There are currently 389 fully operational ethanol plants in Brazil, with another 107 new plants under development (Lemos, 2007). Brazil is currently the world’s second largest producer of ethanol, making 4.5 billion gallons last year (Lemos, 2007). Strong demand, especially in the United States, has increased Brazil’s production quota by 10% for 2007, with estimates of 9 billion gallons/year by 2013 (Lemos, 2007). Brazil is also the world’s leading exporter of ethanol, exporting 845 million gallons in 2006 (a 20% increase since 2005) (Lemos, 2007). Unlike corn based ethanol found in the

U.S., Brazil uses sugarcane to produce its ethanol. Sugarcane ethanol is five times more efficient (in terms of energy output yield/gallon) than corn based ethanol. In addition, 80% of the cars sold in Brazil are “flex-fuel” vehicles, meaning they can run on either ethanol or gasoline, which further lessens Brazil’s dependence on gasoline (Lemos, 2007).

Along with these many benefits, there are some drawbacks associated with ethanol. Since ethanol is an oxygenate, it emits nitrous oxides when it burns, which causes smog levels to increase. Also, ethanol can’t be transported by conventional methods because its high alcohol content is too corrosive for pipelines and large oil tankers (Polyak, 2007). This means new investments in transportation equipment would be required for use nation-wide. In terms of efficiency, ethanol currently gets 25% lower mileage than gasoline, however this results primarily from current engine design, which is optimized for gasoline use (Khosla, 2007).

Thus, as new technologies emerge and ethanol use continues to increase, we can begin to move away from our dependency on fossil fuels. It seems ethanol will be the first big step towards reducing GHG emissions worldwide. Unlike solar and wind power, ethanol requires no major changes in infrastructures. No costly investments in large solar panels or bulky wind turbines have to be made, it is simply placed it in the gas tank just like ordinary gasoline.

A new technology has recently been developed to produce renewable electricity by using plasma arc gasification of municipal solid waste (MSW). Under this technique, MSW is heated to very high temperatures (7,200 to 12,600 degrees Fahrenheit) using plasma arc gasification (PAG) which converts MSW into a synthesis gas composed of carbon monoxide and hydrogen (Young, 2007). The byproducts of PAG are primarily metals and silica glass which can be used to produce other products such as rock wool, floor tiles, roof tiles, insulation, and landscaping blocks (Young, 2007). The synthesis gas can be used to produce electricity and steam through further chemical processing (Young, 2007). Using current technology, a plasma arc facility can generate 30,000,000 kilowatt hours of electricity per year and 1,421,405,000 pounds of steam per year (Young, 2007). This technology would be ideal for use at a nearby ethanol plant, which needs steam and electricity to produce ethanol from corn or cellulosic biomass. Thus, a renewable source of electricity and steam (from MSW) can be used to create renewable fuel (namely ethanol). Also, the need for landfills, which are a source of methane, would be reduced since MSW is used as fuel in a PAG plant. Since current capital investment costs are high ($97.34 million for a PAG plant and an estimated $65 million for an ethanol plant) the implementation of this technology would most likely come from local cities or state governments (Young, 2007).

Many companies are also beginning to capitalize on “green” technologies which would not only help their bottom line, but also positively effect the environment. For example, Albedo Technology International (ATI) recently created a pigmented fertilizer which helps reflect the sun’s solar rays, reducing surface temperatures, carbon dioxide emissions, and the need for water for plants by 80% (Baltatzis, 2006). Torleiv Bilstad, an environmental technologies professor at Norway’s University of Stavanger, explains, “It has the potential to affect both climate change and the 2 billion people living in water-stressed regions of the world.”

(Baltatzis, 2006). ATI plans on selling this product by the end of this year and plans on targeting the $16 billion per year global fertilizer market and the $4 billion per year irrigation market. It also expects net sales to reach $1 billion by 2010 (Baltatzis, 2006). There are also many companies spending million of dollars developing green technology. For example, at Rice University's Carbon Nanotechnology Laboratory joint research ventures funded by several corporations are under way (Biers, 2007). Researchers are attempting to align millions of carbon nanotubes into carbon fibers for use in power transmission lines, which are currently made of aluminum fibers. These aluminum fibers have high resistances and waste large amounts of energy (Biers, 2007).

It is clear that global warming is taking place, and unless we change our habits and our dependence on fossil fuels our planet will become permanently altered even further. We can also see how global warming has a cyclical effect on our environment. As the Earth is warmed from the increasing presence of GHGs in the atmosphere, this causes glaciers to melt which raises sea levels worldwide. Also, global warming causes the permafrost to melt, which releases vast stores of methane gas, further enhancing climate change. As global warming continues to change Earth's climate, nature in turn must struggle to adapt. Seasons are now beginning to change when compared to ten or twenty years ago. In some areas, summers are becoming hotter and longer, while in other places winter comes later and is more severe. This in turn has profound impacts on nature. Plants and animals now have to adapt to these ever present, and growing, changes in their natural habitats. Tribal societies, such as the Eskimo, are now having to cope with food shortages due to these changes. As these alterations become more pronounced, we as human-beings will have to overcome even greater hurdles in order to survive. Reducing global warming can only be accomplished by reducing GHG emissions. This requires a global initiative from all nations to change their energy consumption habits combined with a shift to alternative sources of clean, renewable energy. It is our responsibility as a society to preserve the world in which we live. After all, it’s our only home.

Bibliography

Anonymous. "Amazon Aflame." Environment 39.1 (1997): 23.

Anonymous. "Amazon Burning." Multinational Monitor 20.4 (1999): 4.

Anonymous. "Burning Rainforests." The Ecologist 34.7 (2004): 8.

Anonymous. "Glacier Meltdown." New Scientist 182.2446 (2004): 7.

Anonymous. "Ice Sheets Are Shrinking." Current Science 91.16 (2006): 1.

Anonymous. "The Americas: Brazil's Amazon Forest Burns." The Economist 346.8060 (1998): 38.

Anonymous. "Siberia Is Melting." Current Science 91.4 (2005): 15.

Anthes, Richard A.; Corell, Robert W.; Holland, Greg; Hurrell, James W. "Hurricanes and Global Warming-Potential Linkages and Consequences/Reply to "Hurricanes and Global Warming-Potential Linkages and Consequences." Bulletin of the American Meteorological Society 87.5 (2006): 623.

Baltatzis, Patrick. "A Zip-Lock Bag for Planet Earth." Business 2.0 June, 2006: 28.

Barsh, Russel L. "Fire on the Land: There's Nothing Primitive About Farmers Using Fire to Sustain Biodiversity. In All Reigons of the World, There Is Evidence of Deliberate Periodic Firing of Grasslands and Forests, in Some Cases For Millenia." Alternatives Journal 23.4 (1997): 36.

Beam, Sarah. "Global Warming Brings Regional Cooling." Environment 46.3 (2004): 5.

Behar, Michael. "Reservoir Logs." Wired February, 2007: 88-93.

Bigham, Roy. "Winds of Change." Pollution Engineering 39.2 (2007): 8.

Braithwaite, Roger J.; Raper, Sarah C. "Low Sea Level Rise Projections From Mountain Glaciers and Icecaps Under Global Warming." Nature 439.19 (2006): 311-313.

Braun, Darren. "Welcome to BioTown, USA." Wired February, 2007: 30.

Briers, John M. "Energy (A Special Report): Producers; Texas' New Tea: Houston is Determined Not to Be Left Behind in The Race to a New-Energy Future." The Wall Street Journal 12 February, 2007: R10.

Bulkley, William M. “In the Big Chill, A Researcher Checks Old Ice For Clues to Global Warming.” The Wall Street Journal 9 February, 1994: B1.

Bunyard, Peter. “Crossing the Threshold.” The Ecologist 34.1 (2004): 55-58.

Bursa, Mark. “China Automotive Market Review 2006: Management Briefing: Sales Growth Continues-China Overtakes Japan.” Just-Auto (2006): 1.

Carmichael, Mary; Liu, Melinda. “To Reach for the Moon; China’s Lunar Program is About More Than National Pride. Try This: A Limitless Supply of Clean, Safe Energy.” Newsweek 149.6 (2007): 38.

Chang, Joseph. “Green Machine.” ICIS Chemical Business Americas 271.5 (2007): 3.

“Climate Change and Disease.” Environment 48.2 (2006): 4-5.

“Climate Change Researchers Capture Tyler Prize.” Environmental Health Perspectives 104.11 (1996): 114B.

“Climate for Change.” E: The Environmental Magazine 16.3 (2005): 20, 22, 24-25.

Couzin, Jennifer. “The Forest Still Burns.” U.S. News and World Report 126.15 (1999): 67.

Creffier, Mattias. “Environment: Swiss Glaciers Melting Rapidly.” Global Information Network (2007): 1.

David, Mark. “Are You Taking Global Warming Seriously? MIT Offers Perspective.” Electronic Design 54.24 (2006): 17.

Dooley, Erin E. “Hot New Report On Climate Change.” Environmental Health Perspectives 10.4 (2001): 1.

Fairclough, Gordon. “GM Bets China Will Become Crucial Export Base; CEO Calls Fit ‘A Natural’ As Cost Cutting Intensifies; Shipping to U.S. Not Priority.” The Wall Street Journal (2006): A3.

Geoghegan, John. “Inherit the Wind.” Wired February, 2007: 145-147.

Greenwald, Jeff. “Wish You’d Been Here.” Wired March 2007: 51-53.

Guerrero, Antonio. “Indian Industry Scales New Heights.” Global Finance 20.2 (2006): 14.

Harder, Ben. “China’s Deserts Expand With Population Growth.” Science News 169.9 (2006): 142.

Hecht, Jeff. “Rome’s Ancient Fisheries Confirm Sea-Level Fears.” New Scientists 183.2460 (2004): 14.

Hodgson, Peter; Marignac, Yves. “Is Nuclear Power a Viable Solution to Climate Change?” The Ecologist 31.7 (2001): 20-23.

Holmes, Bob. “Melting Ice, Global Warning.” New Science 184.2467 (2004): 8.

“Hot Topic: Very Big Corn.” The Wall Street Journal (2007): A8.

Humphrey’s, Brent. “My Big Biofuel Bet.” Wired October, 2006: 136-147.

“India Economy: Quick View-Industry Booms.” EIU ViewsWire (2006): 1.

Jones, Philippa. “EC Unveils Renewable Energy Package.” ICIS Chemical Business Americas 271.2 (2007): 12.

Jouzel, Jean; Lorius, Claude; McMave, I.N.; Moore, C.; Raynaud, Dominique. “The Ice Core Record: Past Archive of the Climate and Signpost to the Future.” Biological Sciences 338.1285 (1992): 227-234.

Konrad, Walecia. “Let the Sun Shine.” Fast Company 112.61 (2007): 61.

Kull, Christian A. “Madagascar’s Burning Issue.” Environment 44.3 (2002): 8.

Larson, Janet. “Ice Melt Alert.” USA Today 133.2720 (2005): 33.

Laurance, William F. “Gaia’s Lungs.” Natural History 108.2 (1999): 96.

Leggett, Dave. “Outlook for the Automotive Industry in 2007: Management Briefing: Emerging Markets.” Just-Auto (2007): 12.

Leggett, Jeremy. “Solar Energy: Our Brightest Hope.” Chemistry and Industry 7.3 (2000): 1.

Leiter, Jeffrey. “Energy Politics Extends Beyond The Beltway.” Tribology and LubricationsTechnology 61.12 (2005): 62.

Lemonick, Michael D. “Is Europe Due For a Big Chill.” Time 166.24 (2005): 54.

Lemos, William. “The Brazilian Model.” ICIS Chemical Business Americas 271.5 (2007): 40-41.

Lippsett, Lonny. “Is Global Warming Changing the Arctic?” _Oceanus_ 44.3 (2005): 24.

McGowan, Alan H. “A Future With Nuclear?” _Environment_ 43.6 (2001): 1.

Motavalli, Jim. “The Reckoning.” _E: The Environmental Magazine_ 14.6 (2003): 26-33.

Mounteney, Simon. “Managing Technology: Eastern Promise.” _The Engineer_ (2007): 24.

Osava, Mario. “Climate Change: Deforestation Shares Blame For Brazil’s Gases.” _Global Information Network_ (2004): 1.

Pearce, Fred. “Burning Peat Sparks Global Warming Fears.” _New Scientist_ 9.176 (2002): 11.

Pearce, Fred. “Hot Enough For You?” _The Ecologist_ 32.2 (2002): 38-42.

Perkins, Sid. “Glaciers Give Major Boost to Sea Level.” _Science News_ 171.1 (2007): 14.

Petsonk, Annie. “Climate Change Policy.” _Issues In Science and Technology_ 20.3 (2004): 6-8.

Polyak, Llana. “Alternative Energy: Dwindling Reserves of Expensive, Polluting Fossil Fuels Have Sent Investors in Pursuit of Alternatives to Tradational Energy Sources.” _Financial Planning_ March, 2007: 1.

Rathore, Deepesh; Swarup, Tilak. “A Review of India’s Automotive Industry: Management Briefing: The Light Vehicle Market.” _Just-Auto_ (2006): 11.

Reppert, Barton. “Global Warming: Congress Still Stalled, States and Cities Act.” _Bioscience_ 56.10 (2006): 1.

“Researchers Drill South Pole Snowpack to Determine Century’s Air Quality.” _Bulletin of the American Meteorological Society_ 82.4 (2001): 716-717.

Schmidt, Charles W. “The Kyoto Protocol: Just a Lot of Hot Air?” _Environmental Health Perspectives_ 108.8 (2000): 363-365.

Schulman, Audrey. “Insured Destruction.” _E: The Environmental Magazine_ 13.4 (2002): 16-17.

Sedran, Thomas. “India’s Tempting-But Tricky-Auto Market.” _Automotive Design and Production_ 118.3 (2006): 16.

Sherwonit, Bill. “Alaskan Meltdown: On the Frontlines of Climate Change.” National Parks 78.3 (2004): 24.

Shieber, Jonathan. “Energy (A Special Report): Investors; Power Plays: The Latest on Alternative-Energy Deals From Dow Jones VentureWire.” The Wall Street Journal (2007): R11.

Sim, Peck Hwee. “Coal to Chemicals: Coming Out of the Dark.” Chemical Week 169.4 (2007): 17-20.

Stauffer, Bernhard. “The Greenland Ice Core Project.” Science 260.5115 (1993): 1766-1767.

Teschler, Leland. “Insights on Future Technology.” Machine Design 78.18 (2006): 10.

“United Nations Framework Convention on Climate Change.” Environmental Health Perspectives 108.8 (2000): 353.

Vinayak, Ramesh. “Why We Should Worry; In 40 Years, Key Himalayan Glaciers Have Shrunk By 21%. As the Rate Quickens, Hydro-Power Will Be Badly Hit. Food Crops Will Face Catastrophic Water Shortage. Weather Conditions Could Be Irrevocably Altered.” India Today (2006): 58.

White, Joseph B. “Booming Chinese Auto Market Spurs Car Makers to Stake Claims.” The Wall Street Journal (2006): B6.

Wiener, Jonathan B. “Practical Climate Change Policy.” Issues in Science and Technology 20.2 (2004): 71-78.

Winning, David. “IEA Urges China to Pare Oil Use, Increased Green-Energy Output.” The Wall Street Journal (2006): 11.

Winters, Jeffrey. “Ethanol Equivocation.” Mechanical Engineering 129.2 (2007): 10.

Wohlforth, Charles. “Alaska’s Meltdown.” Onearth 27.2 (2005): 24.

Woodard, Colin. “The Big Meltdown.” E: The Environmental Magazine 16.2 (2005): 19.

Young, Gary C. “How Trash Can Power Ethanol Plants.” Public Utilities Fortnightly 145.2 (2007): 72-76.

Zwirn, Ed. “Fuel For Thought.” ICIS Chemical Business Americas 271.5 (2007): 36-37.