

Excessive Night Lighting

How Your Inefficiencies Can Be Dangerous

A Summary of Light Pollution by:

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Executive Summary:

Artificial Skyglow is not merely an annoyance for astronomers and those missing the night sky. Artificial Skyglow has lasting consequences on the economy, human health, ecological survival and environmental stability. "Among the other casualties of light pollution are the general public's diminished view of the night sky, animals from fireflies to frogs to migrating birds and human health..." (Feder 2005).

As a human being on this Earth, would you pay to lure endangered animals into the highway? Would you pay to watch birds fly into commercial buildings in your city? Would you pay to insure that future generations are unable to catch fire-flies or see many of the animals that walk the Earth today? Do you wish there was a way reduce the pollution equal to 27 million cars and increase the life-time and health of urban trees? While you may not intentionally be causing these irreparable damages inefficient lighting practices cause these problems and more. Read on to: *Part One: Ecological Consequences of Excessive Night Lighting* and *Part One: Environmental Consequences of Excessive Night Lighting* to find out the extent of the damage caused by inefficient lighting practices.

Business Owners:

As a business owner, would you pay the Utility Company an extra \$30 for every light bulb you use? Would you pay an extra 30% of every Utility Bill for electricity you are not using? Is part of your community relations paying money to insure that the community surrounding you had a decreased view of the sky? Hopefully, as a responsible business owner you answered no to these questions. Unfortunately, you may be doing all of these things without your knowledge. To learn more about the money you may be wasting on inefficient lighting practices read on to: *Part One: Economical Consequences of Excessive Night Lighting*

Neighbors:

As a neighbor, would you purposefully leak harmful radiation into your neighborhood that caused the men to lose sleep and cause breast cancer within the women? Would you pay to ensure that the two-thirds of your neighbors are unable to see The Milky Way and most stars? If you are a good neighbor, you would not purposefully do these things. However, you may be causing these damages and more. To learn about the health issues you may be causing you neighbor read on to: *Part One: Biological Consequences of Excessive Night Lighting*

To read about the lasting financial impacts this wasted lighting is having on you and your community read: *Part One: Economical Consequences of Excessive Night Lighting*

Tax Payers:

As a tax payer would you like to continue wasting 2 billion dollars a year in fuel for the single purpose of lighting the night sky? Or would you like to save 16 billion dollars a year? Do you wish there was an easier solution to cutting our energy use by 75% while

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still being able to drive our cars and heat our homes? There is a quick fix to these problems, as well as, methods to save billions of dollars every year. For information read on to: *Part One: Economical Consequences of Excessive Night Lighting*.

For generalized tips on how to improve your lighting practices see *Part Three: What You Can Do and Its Benefits-- Responsible Lighting*

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Part One: The Consequences of Excessive Night Lighting

What is Light Pollution?

Since the beginning of man, he has gazed into the Universe through the night sky. Constellations, galaxies and deep-sky objects make up a panorama of the surrounding Universe that has inspired the foundation to many of our cultures and philosophies. The night sky has influenced our art, literature and science—without it we may very well be lost. This is a threat that we are facing now. “The likelihood of a person born today actually seeing the Milky Way is less than 50 percent”. (Mcfarland 2008) This very real threat is a result of artificial skyglow. In order to thoroughly understand what skyglow is and why it is a problem, it is important to understand how light is normally distributed at night.

There are two types of lighting that affect the night sky: Airglow and Skyglow. Airglow is the natural level of sky brightness that should be present. This includes light from stars, the Milky Way and moonlight (Albers and Duriscoe, Modeling Light Pollution from Population Data and Implications for National Park Service Lands 2001). This natural light is scattered by molecules in the air and produces the “continuous aurora-like glow” that we see (Albers and Duriscoe, Modeling Light Pollution from Population Data and Implications for National Park Service Lands 2001). Natural airglow can also vary depending on the moon cycle or even “...during the course of the sunspot cycle” (Albers and Duriscoe, Modeling Light Pollution from Population Data and Implications for National Park Service Lands 2001). This natural level of light constitutes for the light shine of bright objects in the sky at a level low enough for viewers with average eye functionality to have naked eye visibility of the Milky Way. This is the level of light that the Earth, and all of its inhabitants, were engineered to adapt to at night.

Excess artificial night lighting creates what is known as Artificial Skyglow. Artificial Skyglow is caused primary by “upward light from poorly designed lamps” which allows light to be scattered upwards and reflected by the same molecules designed to gently light the sky using Airglow (Mizon 2000/2002). Walker's Law shows that the Artificial Skyglow produced by a city is linearly related to the population and the inverse 2.5 power of the distance (Albers, Skyglow / Light Pollution 2005).

Skyglow above natural Airglow = 11300000 * population * distance to observer^{-2.5}

In Walker's Law Intensity, Skyglow above natural Airglow is given in nanolamberts and distance is in meters. Since Walker's Law a simplified formula based on [Merle] Walker's work has been proposed by the International Dark-Sky Association: $I=0.01pd^{-2.5}$ (Mizon 2000/2002). Here *distance* is in kilometers.

Artificial Skyglow has grown so intense that two-thirds of the U.S. and half of Europe can no longer see the Milky Way (Cinzano, Falchi and Elvidge 2001). In addition, research conducted by Italy's Pierantonio Cinzano of the Light Pollution Science and Technology Institute in Thience and the University of Padua, predicts that by 2025 "fewer than 100 stars will be visible in most of Italy's population centers" (Feder 2005).

Economical Consequences of Excessive Night Lighting

Many states' and countries' economies are supported by tourists and astronomers flocking to utilize their night skies. In addition to United States National Parks are being significantly harmed by trends in tourism related to local light pollution, state economies are beginning to feel a pinch as well. This can be detrimental to states that depend on their night skies attracting tourists and astronomers. For example, "in southern Arizona ... astronomy brings hundreds of millions of dollars into the state annually..." (Feder 2005). States that depend on tourism and astronomy cannot afford to suffer the consequences of excessive artificial night lighting.

However, while many communities that depend on tourism are suffering due to a lack of night sky attraction, the financial consequences of excessive night lighting are felt far and wide. Business owners, governments and citizens alike are feeling the increased cost of energy. According the Official Energy Statistics from the United States Government the average retail price of electricity has been on a constant climb. While the average retail price of electricity to residential consumers is greatest, at 10.4 cents per kilowatt-hour, every sector has seen significant increases in their ultimate costs of electricity (See Table 1.1). Since 1995 residential and commercial electricity costs have risen by approximately 124%. However, all sectors have increased by 129% from 1995 to 2006.

Table 1.1. Average Retail Price of Electricity to Ultimate Customers by End-Use Sector, 1995 through 2006
(Cents per kilowatt-hour)

Period	Residential	Commercial	Industrial	Transportation	Other	All Sectors
Total Electric Industry						
1995	8.4	7.69	4.66	NA	6.88	6.89
1996	8.36	7.64	4.6	NA	6.91	6.86
1997	8.43	7.59	4.53	NA	6.91	6.85
1998	8.26	7.41	4.48	NA	6.63	6.74
1999	8.16	7.26	4.43	NA	6.35	6.64
2000	8.24	7.43	4.64	NA	6.56	6.81
2001	8.58	7.92	5.05	NA	7.2	7.29

2002	8.44	7.89	4.88	NA	6.75	7.2
2003	8.72	8.03	5.11	7.54	NA	7.44
2004	8.95	8.17	5.25	7.18	NA	7.61
2005	9.45	8.67	5.73	8.57	NA	8.14
2006	10.4	9.46	6.16	9.54	NA	8.9

(Department of Energy 2007)

Energy efficiency overlaps with the reduction of Artificial Night Lighting. According to the New England Light Pollution Advisory Group, “a typical streetlight can cost \$150-\$200 per year to light in electricity costs alone, translating into hundreds of thousands of dollars for towns and millions of dollars per year for cities” (New England Light Pollution Advisory Group 1997). This is very discerning, as “on average, thirty percent of the light from a streetlight shines upwards and outwards” (The Economic Cost of Light Pollution n.d.). The United Kingdom pays dearly for their excessive artificial night lighting. Their nine million street lights amounted to costs of £110 million a year in electricity bills—keeping in mind that thirty percent of that light never hits the ground (The Economic Cost of Light Pollution n.d.). From December of 2007 to December of 2008, the United Kingdom paid £ 119,611,768 for inefficient street-lights (The Economic Cost of Light Pollution n.d.).

In 2003, the International Dark-Sky Association estimated that upward facing light that never hits the ground costs the United States “about 30 million barrels of oil and 8.2 million tons of coal” (Guynup 2003). This is a total of “about U.S. \$2 billion” (Guynup 2003). This wasted energy is very significant because it has long lasting impacts on our economy as well as our international independence.

The United States feeds on oil. While our 1970's interest in renewable energy has been rekindled, we are still solely dependent on foreign oil. This dependence is no secret and enables companies, such as Exxon Mobil, to take advantage of our dependence. While most Americans attribute the recent wars to a rising cost in oil prices it is imperative to analyze one of the basic fundamental accounting equations:

$$\text{Sale Price} - \text{Cost} = \text{Profit}$$

Most oil companies would have you believe that the colossal hike in oil prices that Americans recently experienced was due to a rise in cost because of the war. However, if there were rising costs to produce and ship oil that were comparable to the rising costs that Americans have seen profits would have been marginal and comparable to years before. One would be able to equate a ratio of profit for oil companies and see a range of consistently year to year. However, “Exxon Mobil once again reported the largest quarterly profit in U.S. history ...” (Hargreaves 2008). For those economists and business owners, this would obviously show that if sale price is rising and profit is rising, cost must not be rising. This lack of rising cost could be attributed to scarcity or a sheer monopoly within the energy industry. If everyone has bread you can only charge 89 cents; however, if you are the only person that has bread you can charge 30\$ for a loaf of bread. If you were in a time where bread costs 30\$ a loaf, would you feed it to the ducks? By illuminating the night sky and allowing your light to escape you are wasting an enormous amount of funds nightly.

With the 2008 housing and credit crashes the American economy is in recession. According the International Council of Shopping Centers consumer spending was the worst it has been since measurements began in 1969 (CNN 2008). This is a direct result of the recession that United States has been suffering from since December of 2007 (CNN 2008). Although this recession was jump started by a housing and credit market crash which lead to a failing job market, others are remarking upon the massive amount of American dollars that are allocated to oil. One such author referenced rising oil rising since the beginning of the war in Iraq: "With American so dependent on oil imports we had to spend several hundred billion more to purchase oil – money that otherwise would have been spent on American goods" (Stiglitz 2009). A portion of this several billion dollars of oil is wasted electricity. This is money that would have gone to buying American goods and stayed within our economy. A country's independence is a measure of imports versus exports. With Americans wasting electricity and demanding more we are weakening our economy by gorging ourselves on foreign products, mainly oil.

In addition to paying for light that never hits the ground, the United States will have to invest over ten trillion dollars in order to accommodate the expected increase in demand for electricity (The Climate Group n.d.). The global demand is set to double, from 17,408TWh to 30,364TWh, between 2004 and 2030 (The Climate Group n.d.).

The economic consequences of excessive night lighting exist outside of the electric bill as well. We continue to waste over priced foreign oil, and in doing so threaten our vanishing independence and strength in the world market. We neglect to see the manifesting affects that our overconsumption through waste has on our economy. If Americans had not been wasting billions of dollars for the sake of lighting the sky "because we can" our independence and market strength may not have been called into question, as it now. If we had years of accumulated money saved by efficient light practices a seven hundred billion dollar bailout may not have been so detrimental to our economy.

Biological Consequences of Excessive Night Lighting

While the financial consequences of excessive night lighting may be straight forward the biological consequences of excessive night lighting are not. It has taken numerous studies to predict and confirm the effect that artificial night lighting has on the human body. Among these inherent harms are weakened immune systems and cancer. It is important the every person living in a highly lit community read these studies and familiarizes themselves with these consequences, because neighbors' bright lights or a car dealerships' obtrusive night lighting are more than an annoyance and can significantly shorten your life.

"Artificial lighting ... interferes with the production of melatonin"—which controls the circadian rhythm (Dillon and Newspapers 2008). Studies have shown that "melatonin has been found to ward off cancer" (Dillon and Newspapers 2008). Recent

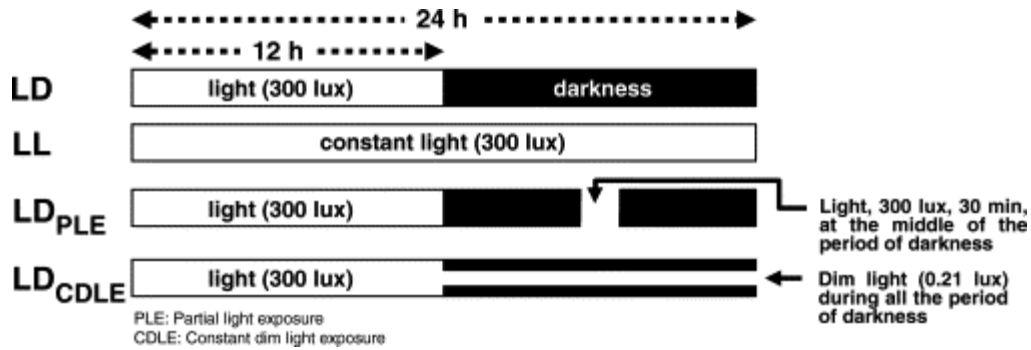
studies have found that when circadian rhythms are disrupted by excessive artificial night light humans experience increased rates of cancer (Feder 2005). The Circadian Rhythm is the daily biological and chemical oscillations that occur in humans (Muskoka Heritage Foundation 2004). When visible light hits the human retina it triggers the circadian responses, which lead to "hormonal changes in the pituitary, pineal, adrenal and thyroid glands" (Muskoka Heritage Foundation 2004). Some of these hormonal changes are meant to cease at night, in darkness. However, when a person is unable to sleep in complete darkness due to excessive night lighting the Circadian Rhythm is interrupted and the neuroendocrine changes that would normally occur at night do not and hormone changes continue (Muskoka Heritage Foundation 2004).

According to Dr. Joan Roberts, Ph.D., a featured professor in melatonin/circadian immune response research, "all living things need a certain period of darkness and then quality daylight in order to function properly" (Muskoka Heritage Foundation 2004). Thus, excessive lighting in neighborhoods disrupts this fundamental biological need. Dr. Roberts has found through her research that "...particularly light in the evening [leads to] severe damaging emotional and physical effects associated with seasonal depression (SAD), jet lag..." (Muskoka Heritage Foundation 2004).

Multiple studies have shown an "inverse association between breast cancer incidence and degree of visual impairment" (Cos 2006). In addition, several tests have also shown that there is a "high incidence of breast cancer among women exposed to light during night, such as shift workers" (Cos 2006). One such study showed that Israeli women in neighborhoods that had night light bright enough to read a book "... had a 73 percent greater chance of getting breast cancer than women who live in areas that receive light from the stars" (Dillon and Newspapers 2008). Thus, proving that excessive night lighting can be not only disruptive to sleep; but can produce a seventy-three percent higher rate of breast cancer in women than seen in naturally lit night skies.

These studies were further confirmed by the University of Cantabria's Department of Physiology and Pharmacology in *Exposure to light-at-night- increases the growth of DMBA-induced mammary adenocarcinomas in rats*. This experiment used female rats fifty-five days of age and broke them into four groups, sixteen rats each, of different photoperiods:

Figure 1.2 Rat Light Stages



Those rats in groups LL, LD_{PLE} and LD_{CDLE} “showed significant higher rates of tumor growth than animals under LD photoperiod” (Cos 2006). In addition, “the average tumor size in those rate in LD_{CDLE} was significantly larger” (Cos 2006). This experiment concluded that “the constant dime light exposure at darkness (LD_{CDLE}) seems to be the greatest tumor growth-inducer (Cos 2006). These conclusions confirmed all early studies and found that many of those in group LD_{CDLE} died before the twelfth week of the experiment (Cos 2006).

The complete extent of the biological damage done by excessive night lighting has not yet been discovered. However, it is clear through current research that the effects of excessive night lighting are detrimental to the human body and psyche. These effects reach far beyond losing a night’s rest. It is evident through the significant damage done to the human body by excessive night lighting that excessive night lighting is a far more serious problem than known and deserves immediate attention.

Ecological Consequences of Excessive Night Lighting

As with humans, there are significant ecological consequences of excessive artificial night lighting. “986 species of bats, most smaller carnivores and rodents, 20 percent of primates, and 80 percent of marsupials are nocturnal” (Guynup 2003). Thus, through excessive night lighting their habitat is being invaded and destroyed. A few of

the more noted affected species include: Beach Mice, glow worms, sea turtles and numerous birds.

One very significant effect that excessive night lighting has on nocturnal animals is the invasion of their habitat. Many nocturnal animals depend on the security of the dark night for protection from predators. The endangered Beach Mouse is one of these affected animals. "Increased lighting makes the mice more visible, and that can only increase their vulnerability to predators" (ScienceDaily: Lights From Beachfront Development Harm Endangered Beach Mice 2004). While making mice visible does not strike this average person as dangerous, this mouse is on the brink of extinction and through the continued trespass of light into his habitat he may be extinct very soon.

An additional endangered species threatened by excessive night lighting is the sea turtle. "Sea Turtles are federally listed as threatened and endangered, and have been protected by the Endangered Species Act since 1973" (Miller 2008). Like the Beach Mouse, increased artificial night lighting poses a threat to make the sea turtle more vulnerable to predators. Excessive night lighting trespasses into the sea turtles nesting beaches. "Light pollution on nesting beaches is detrimental to sea turtles because it alters critical nocturnal behaviors, namely, how sea turtles choose nesting sites, how they return to the sea after nesting, and how hatchlings find the sea after emerging from their nests" (Witherington and Martin 2003). It is critical that the endangered sea turtles' nesting grounds are undisturbed in order to insure proper reproduction and population growth. However, "mothers can become disoriented by strong lighting, wander out to a road, fall in a pool or use all their energy before nesting" (Miller 2008). According to Michael Salmon, a biologist at Florida Atlantic University in Boca Raton, Florida, even if the mothers are able to nest "hatchlings are attracted to lights and crawl inland, or crawl aimlessly down the beach, sometimes until dawn, when terrestrial predators or birds get them" (Guynup 2003).

The Glow-worm has been a symbol of American childhood summers for decades. "The [glow-worm] need[s] only a regular food supply and a dark environment to thrive" (Mizon 2000/2002). The three largest threats to the glow-worm are changes in habitat, artificial lighting and pesticides (Glow-worm alert for dog walkers 2005). However, through excessive night lighting their numbers are beginning to drop. In the last thirty years "... the encroachment of artificially bright skies over their habitats is the cause of a rapid decline in glow-worm numbers..." (Mizon 2000/2002). They are in such danger that "they have been identified in the lowland Derbyshire local biodiversity action plan as a species that need protection to ensure their survival" (Glow-worm alert for dog walkers 2005).

Birds of all types are severely affected by excessive artificial night lighting. Nocturnal birds, such as owls, face many challenges as they try to adapt to excessive artificial night lighting. "Light pollution reduces the suitable area of feeding habitat for owls and other night-hunting birds" (The Threat to Wildlife n.d.). In addition, excessive lighting "can illuminate nesting colonies on rocky coasts and islands, causing problems tending nests, abandonment of eggs or chicks, and increased predation by gulls or owls" (PRBO Conservation Science 2008). Like other bird species, sea birds are "drawn to or distracted by lights, seabirds can fly onto decks or land where they may be trapped, injured, or killed." (PRBO Conservation Science 2008) "In the USA and Canada there is growing concern over the increasing number of migrant birds dying as a result of hitting illuminated buildings at night" (The Threat to Wildlife n.d.). Experts say "migrating birds may die in hundreds or even thousands nightly in cities dominated by

skyscrapers" (New York dims lights to aid birds 2005). Many cities have spectacles of dead birds resulting from such events because "lights can distract birds from feeding, navigating, and other vital activities" (PRBO Conservation Science 2008).

The effects of excessive night lighting are detrimental to numerous species. Even more troubling, is the fact that many of the species affected are already on threatened or endangered lists; thus, encompassing the cessation of excessive night lighting into the efforts of preservation of numerous species. The cessation of excessive night lighting is quickly becoming a matter of national biodiversity and soon the choice may be made for those sharing their environment with endangered and threatened species affected.

Environmental Consequences of Excessive Night Lighting

How Light Pollution Translates Into Air Pollution

In connection with the economic consequences of excessive night lighting are the environmental consequences of excessive artificial night lighting. National Parks who's surrounding areas' economic stability is based upon tourism and attracting astronomers are noted to have pristine skies—such as Arizona (Albers and Duriscoe, Modeling Light Pollution from Populoation Data and Implications for National Park Service Lands 2001). Large areas of pristine skies can also be seen in Nevada, Montana, North Dakota, eastern Oregon, southeastern Utah, western Texas and Wyoming—“these regions were far enough from large urban centers that the influence of light pollution was minimal” (Albers and Duriscoe, Modeling Light Pollution from Populoation Data and Implications for National Park Service Lands 2001). However, these few locations are far from large cities that threaten to impede on tourists' view. In reality, “many “wild” national park areas are surrounded by, on, in close proximity to large urban centers, leading to a degradation of the view of the night sky” (Albers and Duriscoe, Modeling Light Pollution from Populoation Data and Implications for National Park Service Lands 2001). Having already discussed the economic implications of excessive night lighting trespassing into National Parks, it is imperative to investigate the environmental repercussions of light trespass into United States National Parks.

National Parks are essential to the United States. They have represented employment in times of recession and depression, remove vast amounts of pollutants from the air we breathe, and are refuge to many of the United States' wildlife. They provide not only an emotional escape for citizens, but quit literally fresh air.

“Land use issues are of particular interest to the United States because U.S. forests and soils annually sequester large amounts of carbon dioxide” (Energy Information Administration 2001). United States forestry offsets approximately fifteen percent of all U.S. Carbon Dioxide emissions (Energy Information Administration 2001). The United States Environmental Protection Agency (EPA) estimated the annual U.S. carbon sequestration for the year 2000 at 246 million metric tons carbon equivalent; however, this was a sharp decline of 17.7 percent from the 299 million metric tons carbon equivalent sequestered in 1990 (Energy Information Administration 2001). See Figure 1.3.

Figure 1.3 ““Net CO₂ Flux from Land-Use Change and Forestry (Tg C)”

Sink Category	1990	1995	1996	1997	1998	1999	2000
Forests	(268)	(267)	(277)	(207)	(205)	(208)	(210)
Urban Trees	(16)	(16)	(16)	(16)	(16)	(16)	(16)

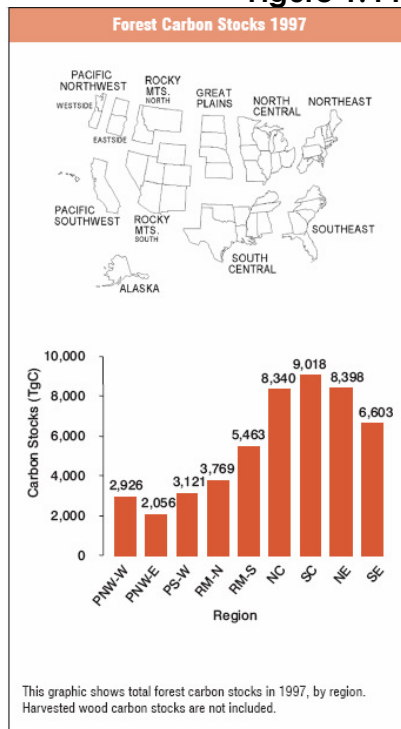
Agricultural Soils	(10)	(16)	(16)	(17)	(18)	(19)	(18)
Landfilled Yard Trimmings	(5)	(3)	(3)	(3)	(2)	(2)	(2)
Total	(299)	(303)	(302)	(242)	(242)	(245)	(246)

(U.S. Environmental Protection Agency 2002)

According to the United States Environmental Protection Agency this decline was primarily due to a decline in the rate of net carbon accumulation in forest carbon stocks:

- Trees (i.e., living trees and standing dead trees, including the roots, stems, branches, and foliage);
- Understory vegetation (i.e., shrubs and bushes, including the roots, stems, branches, and foliage);
- Forest floor (i.e., fine woody debris, tree litter, and humus)
- Down dead wood (i.e., logging residue and other coarse dead wood on the ground, and stumps and roots of stumps)
- Soil (i.e., organic material in soil)."

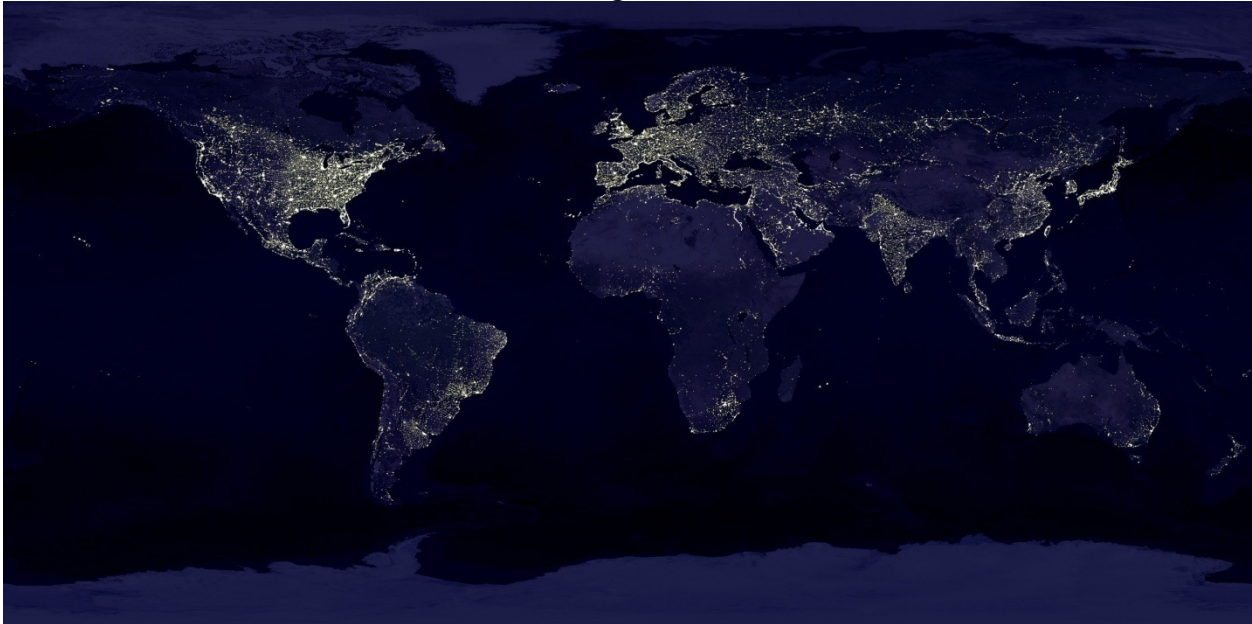
Figure 1.4 Forest Carbon Stocks in 1997



(U.S. Environmental Protection Agency 2002)

With such a substantial decrease in forest carbon stocks it is critical to decipher possible contributing factors. Figure 1.4 Forest Carbon Stocks in 1997 depicts where the largest and most *productive* forest carbon stocks are located. With that in mind compare the locations of the largest forest carbon stocks to the photograph taken by NASA in 2000 figure 1.5:

Figure 1.5 Earth's City Lights



(NASA 2000)

The areas that had the highest forest carbon stocks in 1997 (North Central, South Central, North East and South East) are also the most highly lit areas of the United States in 2000. While, a city to city change in forest carbon stocks is currently unavailable, the fact that the majority of forest carbon stocks reside in, what are now, the areas most affected by excessive night lighting is significant. This change in CO₂ flux may be a result of drop in forest health within these areas. Although this theory it yet to be proved, it is clear that forest preservation will be a priority for the United States in the coming years until a solution is reached.

In addition to forest carbon stocks, urban trees are also key pollution removers in United States. In 2006 “pollution removal (O₃, PM₁₀, NO₂, SO₂, CO) varied among cities with total annual air pollution removal by US urban trees estimated at 711,000 metric tons” (Nowak, Crane and Stevens 2006). The dollar value of the pollutants removed by urban trees for the year 2006 was \$3.8 billion (Nowak, Crane and Stevens 2006). Urban trees are an essential asset to the United States of America and should be preserved at all costs—especially with the detrimental decline in forest carbon sequestration.

Trees, like animals, are meant to have sunlight in the day and darkness at night. They require wavelengths of 400-450 nm and 625-700 nm for photosynthesis (Chaney n.d.). The photoperiod controls the tree's vegetative growth and reproductive activities requiring 625 nm to 760 nm; however, the photoperiod of a tree can be induced with

as little as 0.06 to 3 $\mu\text{E}/\text{m}^2/\text{sec}$ (Chaney n.d.). This is about 15 times brighter than a full-moon and almost half as bright as a 100 watt incandescent bulb at five feet away (Chaney n.d.). However, because of excessive night lighting trees, depending on location, undergo harsh artificial light 24/7. This constant bombardment of lighting on trees causes them to be in constant photoperiod and undergoing photosynthesis. Through the disruption of their cycles trees are unable to adequately rest at night, as they are engineered for, and are unable to prepare for harsh winters. Due to these conditions, urban trees may be becoming over exhausted which may lead to even further drops in carbon sequestration within city limits and the United States as a whole. While some may believe that continual replanting of dead tree may be a solution, seedlings and young trees are unable to adapt to night lighting and will die off quickly.

According to William R. Chaney, Department of Forestry and Natural Resources at Purdue University, the popular incandescent and high pressure sodium light have a very high potential effect on trees and attributes the increased reporting of injuries to woody plants to the introduction of the high pressure sodium lamp¹ (Chaney n.d.). Chaney also states that the newer fluorescent, mercury vapor and metal halide have a low potential effect on trees (Chaney n.d.). Thus, if consumers and commercial operations want to lower their affect on urban trees fluorescent, mercury vapor and metal halide bulbs would, addition to conservative light practices, reduce future lighting damages to urban trees.

¹ See Part Three: Responsible Lighting for more information and tips.

Part Two: Current Efforts for the Cessation of Excessive Night Lighting

Laws Prohibiting Excessive Night Lighting

The United States recognizes our energy independence as a matter of national security. In August 2005 President Bush signed The Energy Policy Act. This act "encourages energy conservation and efficiency by promoting residential efficiency, increasing the efficiency of appliances and commercial products, reducing Federal government energy usage ..." (The White House 2007). Utilizing conservative lighting practices is part of residential efficiency. By increasing our efficiency at home we will be working towards wasting less oil and in turn be supporting our home country.

However, in the end, policies concerning excessive night lighting have to be enforced by law. While the government is fighting to secure our independent from foreign oil and our strength within the world market there are those that completely disregard their neighbors, communities and national economy. Unfortunately, only laws and regulations that threaten monetary punishment and imprisonment are strictly adhered to by the greater majority of the population. There are several regulations in place and continuing efforts, both in the United States and world-wide, that work to reduce excessive artificial night lighting. These efforts range building code enforcements and county environmental efforts to enforcing light trespass as a nuisance.

According to some lawyers approaching light pollution from the town and county perspective is the most effective (Jewkes 1998). Arizona and California have made an effort to control light pollution by enforcing the following: "installing hooded streetlights, limiting lights at residences and turning off business lights" (Dillon and Newspapers 2008). The new standard for new installation of safety lighting on State highways is a full-cutoff lamp head (California MUTCD (Manual on Uniform Traffic Control Devices) n.d.). This is the general format in which cities and counties can hope to reduce excessive night lighting. These types of laws have made leaps and bounds within these specific limits and will hopefully become contagious to surrounding areas.

As of December 1 2008, Kansas City began efforts to retrofit their 90,000 street lights with flat-lens lamps (Dillon and Newspapers 2008). In addition, Kansas City is pushing for a ordinance that would "prohibit flashing or revolving exterior lights from visible outside the property line", "require all outdoor lighting to be reflected away from homes and streets" and "require light fixtures under gas station canopies to be recessed" (Dillon and Newspapers 2008). This type of ordinance helps protect the population and environment from residential and commercial light trespass.

Calgary and Alberta, Canada, have also taken several steps to update their regulations and try to control light pollution (Dillon and Newspapers 2008). Between 2002 and 2005, the City of Calgary, Canada, switched 37,500 dropped lens "cobra head" fixtures to the lower-wattage, flat lens EnviroSmart fixtures (The City of Calgary 2008). Savings "are estimated at \$1.7 million per year, while energy savings are estimated at 25,000 MWh" (The City of Calgary 2008). Through their efforts "street lighting on residential and collector roads will continue to meet minimum Illuminating Engineering Society (IES) guidelines." (The City of Calgary 2008) The City of Oslo, Norway, also revamped city planning in order to control light pollution. The installation of intelligent street-lighting lead to an energy savings of 60 -70% (The Economic Cost of Light Pollution n.d.). Many additional locations have began to try and control excessive night lighting by mandating remodeling and new commercial properties to comply with current engineering that is striving to eliminate light pollution. Awareness of the financial advantages that cities such as these have gained through establishing conservative lighting will perhaps cause contagiousness of conservative lighting practices, at least throughout North America.

Some countries have taken to declaring light trespass a nuisance, specifically Scotland. Light trespass is "that artificial light emitted from premises or any stationary object so as to be prejudicial to health or a nuisance constitutes a statutory nuisance" (The Stationery Office Limited as the Public Health etc. 2008). Simply, light trespassing is shining light onto someone's property that would be considered a nuisance; whereas, "a nuisance arises from a substantial interference with an individual's use and enjoyment of his or her property" (Jewkes 1998). While approaching excessive night lighting from a nuisance point of view does not stress the biological dangers created by excessive night lighting it does stress that excessive night lighting interrupts one's ability to fully enjoy their property. There is an exemption, however: "... in relation to those premises referred to in section 79(2) (namely, premises occupied for naval, military or air force purposes) ... [and] ... to exclude artificial light emitted from lighthouses from the scope of the statutory nuisance regime in Part III" (The Stationery Office Limited as the Public Health etc. 2008). Therefore, Scotland has recognized light trespass as a nuisance but recognized, rationally, that the military and lighthouses do require a certain amount of excessive night lighting.

The Intergovernmental Panel On Climate Change and the United Nations Framework Convention on Climate Change (UNFCCC) are pushing for elaboration in Kyoto Protocol Land-Use Change and Forestry Sector of the Guidelines Sustainable development including a broad range of environmental, social, and economic impacts such as: biodiversity; the quantity and quality of forests, grazing lands, soils, fisheries, and water resources; the ability to provide food, fiber, fuel, and shelter; employment, human health, poverty, and equity (Intergovernmental Panel On Climate Change 2000). These goals are working to solve for the biological, ecological, economical and environmental damages summarized in earlier chapters. Through this work forests could be set aside as carbon stocks and begin to receive the attention needed to ensure the future of our wildlife species, air quality and life quality.

Efforts for the Cessation of Ecological Effects of Excessive Night Lighting

The United States Fish and Wildlife Service have instituted numerous events and workshops in order to educate the communities in which animals affected by artificial night lighting habitat. In an effort to create awareness in an Alabama community, the U.S. Fish and Wildlife Service initiated the Alabama Sea Turtle Lighting Workshop (Miller 2008). This workshop was "aimed to show residence how to minimize the affect they have on nesting sea turtles and their hatchlings" (Miller 2008). The U.S. Fish and Wildlife Service education the community regarding responsible lighting practices and assured the community "with darker beaches, more female sea turtles would be attracted to nest here, increasing the number of hatchlings and helping the recovery of these threatened and endangered species," (Miller 2008).

Birds are significantly harmed by excessive night lighting, as stated in the earlier ecological chapter. Birds use light to guide them through migration season. Numerous accounts of mass deaths of birds have been attributed to the rising of excessive night lighting. "The single biggest recorded bird collision in New York happened in 1948, when about 800 birds died after flying into the brightly illuminated Empire State Building on a foggy night" (New York dims lights to aid birds 2005). In 1975 one of the largest *Lights Out* events was begun by the Empire State Building. During migration periods, "this usually means about 10 weeks in spring and 10 more in the fall, between the hours of midnight and daylight", the Empire State Building will shut off its lights in an effort to aid in bird migration and try to prevent the deaths of numberless birds (Audobon n.d.). While this act of good will does prevent the deaths and misguided migration of countless birds some are discouraged by the lack of contagiousness of the event.

"Whether a significant step in preventing urban bird collisions or not, Lights Out is helping the birds anyway. Burning less energy helps to preserve their habitat." (New York dims lights to aid birds 2005)

In Toronto, Canada, The Fatal Light Awareness Program (FLAP) arose. This program was created to save birds from their untimely head-on collisions with skyscrapers. FLAP focused on publicizing the problem and working with tower staff, cleaning crews, security and management to turn off the lights at night end.

Through increased awareness of the dangers and lasting impacts that excessive night lighting has on our wildlife the efforts for the cessation of excessive night lighting become more recognized as a necessary act of communities. These programs fight towards preserving species affected by excessive night lighting and through their hard work the financial incentives of responsible night lighting are beginning to be recognized, or at least noted.

Efforts for the Cessation of Economical Effects of Excessive Night Lighting

How Companies and Households Have Saved Millions

Lights Out, hosted by the Empire State Building every migration season, is a great example of how energy efficiency and the reduction in excessive artificial night lighting. It is difficult to pinpoint exactly which companies are striving towards making their companies more energy efficient and reducing the excessive artificial night lighting. However, there are many governmental aid programs available to assist companies in becoming more “green”, as well as a number of public/private partnerships that are attempting to make the transition less costly and more manageable.

An excellent example of a company promoting education and opportunities in the reduction of excessive night lighting is the California utilities company Pacific Gas & Electric. In a 2008 U.S. House of Representative Briefing on light pollution PG&E was named “a leader in promoting products that simultaneously meet both goals [energy efficiency and reduction in light pollution]” (U.S. House of Representatives Briefing 2008). Through the emerging technologies at PG&E their core beliefs that “outdoor lighting regulations should promote lighting design practices that are consistent with energy conservation, safety needs, and the preservation of the natural night environment” are clear (Pacific Gas and Electric 2008).

In October of 2008, PG&E partnered with ENERGY STAR and launched a “groundbreaking campaign to hand out 1 million compact fluorescent light bulbs (CFLs) as part of ENERGY STAR's Change a Light, Change the World campaign” (Pacific

Gas and Electric Company 2008). In PG&E's own words: "ENERGY STAR is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy helping us all save money and protect the environment through energy efficient products and practices" (Energy Star n.d.). The use of CFLs is promoted throughout ENERGY STAR and PG&E due to the fact that they consume 75 percent less energy than traditional incandescent lamps (Pacific Gas and Electric Company 2008). Through their practices PG&E was excited to announce in 2008 that " ... since 1976, PG&E and our customers have kept over 135 million tons of carbon dioxide (CO₂) out of the atmosphere, based on cumulative lifecycle savings" (Pacific Gas and Electric Company 2008).

Efforts for the Cessation of Environmental Effects of Light Pollution

A newly discussed proposal among scientists to aid in the cessation of environmental effects of light pollution is the fight to create dark sky preserves. Pierantonio Cinzano's research, of the Light Pollution Science and Technology Institute in Thiene and the University of Padua, show increasing light pollution. According to Cinzano "the night sky is very endangered" (Feder 2005).

Scientists everywhere agree "... the skies are widely considered a natural resource", (Feder 2005), and that it would be appropriate to announce the dark sky as endangered and begin efforts to create preserves. Biologists agree: "designating a dark sky as a natural resource which is as worthy of protection as an old growth forest or a scenic river may seem odd, but biologists worry about the ultimate impact caused by this little-understood ecological disturbance" (Guynup 2003). Researchers Steve Albers, of the National Oceanic and Atmospheric Administration and Forecast Systems Laboratory, and Dan Duriscoe, of Sequoia and Kings Canyon National Parks and Three Rivers, believe that "park areas that are both remote from large urban centers and are primarily wilderness parks should be identified as candidates for dark sky preserves" (Albers and Duriscoe, Modeling Light Pollution from Population Data and Implications for National Park Service Lands 2001).

While this concept may be odd for some, it is not unheard of to restrict lighting on land for the sake of the night sky. In West Texas “McDonald Observatory has teamed up with the Nature Conservancy to buy nearby land and resell it with restrictions on lighting” (Feder 2005). This type of partnership may be what the future holds if measures are not taken and acted upon now in order to ensure that dark skies are more than a distant memory.

Part Three: What You Can Do and Its Benefits

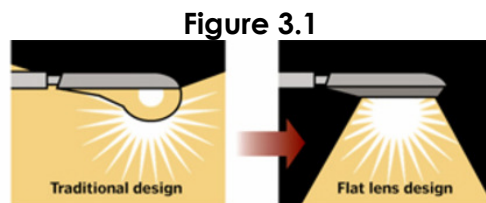
Responsible Lighting

"The frugal Empire State Building has been doing it since 1975, and now it may be time for others to join." (New York dims lights to aid birds 2005)

A great start to ending light pollution is through creating awareness and taking a stand. Precedence has been set forth in which light trespass is a nuisance. "A nuisance arises from a substantial interference with an individual's use and enjoyment of his or her property. The action can only be pursued by the individual whose rights have been affected" (Jewkes 1998). Courts have ordered neighbors to stop using excessive night lighting due to individuals' rights to enjoy their dark back-yard being interrupted, as well as, interrupting fisherman during fishing seasons (Jewkes 1998). You can solve for light trespass in your neighborhood by taking a stand and reporting light trespass.

The population is slowly becoming aware of the irreparable damage that excessive night lighting can cause in all sectors of life. One of the most effective ways to spread awareness and influence is to lead by example. Through the efforts of engineering there are numerous lighting options available to you. Responsible lighting includes more than turning off the lights; it includes choosing lighting equipment that will perform the task needed as efficient as possible. An efficient lighting fixture will translate into less light pollution, less energy waste and finally eliminate financial waste.

It is important to choose a lamp head that reflects ALL of the light you are paying for onto what you are trying to illuminate. Cut-off lamp heads ensure that light is not directed upwards or horizontal. (See figure 3.1) Figure 3.1 illustrates the tradition design that allows an enormous amount of light to escape, as well as, the flat lens designed to direct light accurately.



(Dillon and Newspapers 2008)

According to Bill Wren a dark skies consultant: “by shielding [light] you can usually end up with about the same amount of light on the ground for about half the cost” (Feder 2005). It is also crucial for trees that they are protected from excessive artificial night lighting. (See Figure 3.2 & 3.3)

Figure 3.2

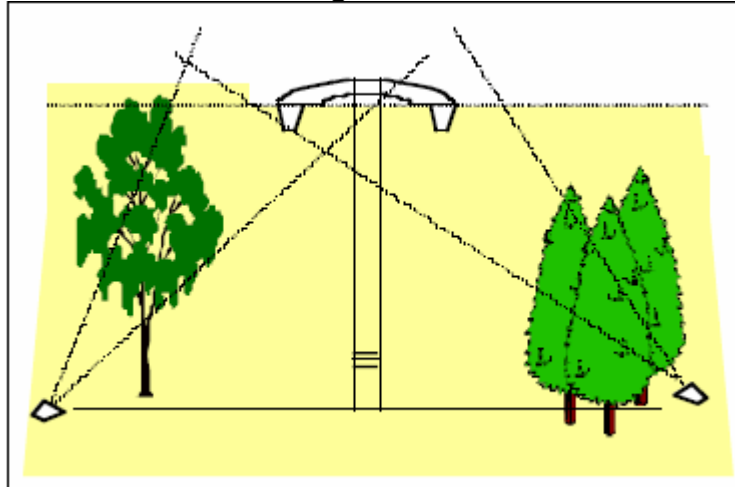
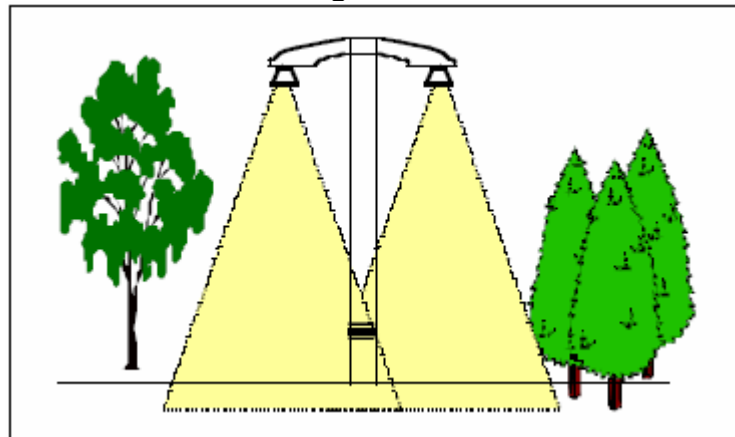


Figure 3.3



Properly installing cut-off lamp heads and tree-friendly bulbs can lower the damaging effects that trees experience as a result of excessive night lightings. (See *Part One: Environmental Consequences of Excessive Artificial Night Lighting*).

Choosing the right type of bulb to install in your light fixture is just as crucial as the lamp head. Different light bulbs emit different wavelengths. When picking which light bulb is appropriate consider the energy efficiency of the bulb, as well as, any potential effect it may have on surrounding trees or vegetation.

Understanding the different wavelengths produced by different bulbs can be helpful when deciding which bulb to use. Infrared light increase motion on whole objects and can induced photoperiodism of trees. Ultraviolet, does not induce photosynthesis or photoperiodism; however, because ultraviolet light carries so much

energy it breaks the covalent bonds of many organic molecules. Thus, “ultraviolet light can destroy the complex biochemical machinery of photosynthesis” (Molles Jr. 2008).

The best solution is to stick to a bulb that produces wavelength within the visible light spectrum, 380 nm to 760 nm. This light will induce photosynthesis so it is crucial to keep excess artificial night lighting off your trees. If it is impossible to accomplish this, try to stick to pine trees that have a low sensitivity to artificial light (Chaney n.d.).


Mercury lamps are an option; however, “the IDA reports that some Arizona lighting ordinances prohibit the installation of new mercury lamps, on the grounds of tier inefficiency” (Mizon 2000/2002). “Changing over to MH [metal halide], LPS [low pressure sodium], or HPS [high pressure sodium] lamps should accompany a cut of 40 to 60 percent in streetlight costs, via the lowering of wattage on the new lamps” (New England Light Pollution Advisory Group 1997). High Pressure sodium lamps emit high red to infrared wavelength which can have a high effect on trees (Chaney n.d.). Low pressure sodium lights are very big and difficult to install. Metal halide lamps have a low effect on trees (Chaney n.d.) and are “...more energy efficient than mercury lamps...” (Mizon 2000/2002). Another good option is Compact Fluorescent Light bulbs (See figure 3.4).

Figure 3.4

LIGHT OUTPUT EQUIVALENCY

To determine which ENERGY STAR qualified light bulbs will provide the same amount of light as your current incandescent light bulbs, consult the following chart:

INCANDESCENT LIGHT BULBS	MINIMUM LIGHT OUTPUT	COMMON ENERGY STAR QUALIFIED LIGHT BULBS
WATTS	LUMENS	WATTS
40	450	9-13
60	800	13-15
75	1,100	18-25
100	1,600	23-30
150	2,600	30-52

 LEARN MORE AT energystar.gov

(Energy Star n.d.)

Compact Fluorescent Light Bulbs or CFLs have numerous advantages including:

- Use 75 percent less energy than incandescent
- Produce 75 percent less heat than incandescent
- Save 30\$ or more in electricity costs over each bulb's lifetime.
- last up to 10 times longer than incandescent

The BIG Picture

“As light pollution has originated and accelerated for the last 50 or 70 years, astronomers have gone to more and more remote areas—to remote mountaintops and remote countries. There are no further places to run.” Chris Luginbuhl, an astronomer at the IS Naval Observatory. (Feder 2005)

There are hundreds, if not thousands, of Astronomers working together world-wide to help combat light pollution. Astronomers Without Borders encourages others to follow its philosophies: “One People, One Sky”, “we all share the same sky”; “passion to share the night sky crosses international borders and cultures as well” (ASTRONOMERS WITHOUT BORDERS, INC 2008).

The IAU Commission 50 was established in order to protect sites for optical astronomy and work to control light pollution. The International Dark-Sky Association held its first Congressional briefing June 20, 2008 in a hearing room of the Science and Technology Committee of the U.S. House of Representatives. The efforts of these astronomers and scientists are beginning to be seen and the long lasting effects of light pollution are beginning to be recognized.

However, it is important for the world to realize that light pollution is not merely an annoyance. Light pollution has long lasting negative impacts on all facets of life. According to Malcolm Smith, president of the International Astronomical Union's Commission 50, “in 10 years we will have more biologists and medics at our meetings than astronomers” (Feder 2005).

Communities throughout the world are beginning to realize the significant advantages of turning off a few lights and promoting conservative lighting practices. Some community papers are remarking upon how “creating darker beaches by removing what is referenced as light pollution is the key to sea turtle recovery and residents, as well as beachfront business owners and coastal municipalities, can make a difference” (Miller 2008). In addition to small communities realizing how large or an impact that can make, they are also remarking upon the ease of transition and financial advantages: “Lighting is one of the greatest threats to sea turtles on land but the easiest and most affordable to correct” (Miller 2008).

More and more is being discovered concerning the long lasting negative impacts that excessive night lighting can have on the world. Noxious lit signs are becoming a common appearance on highways. These signs, coupled with poorly designed street lighting, are beginning to gain attention from annoyed drivers. The

glare caused by these signs and lamps are dangerous to motorists. The glare caused by these signs and lamps may pave the future for city and state –wide class action suits to ban poor lighting practices. However, for now any legal action is restricted to those personally report a light trespass as a nuisance in their life.

Light pollution will inevitable gain forefront in one of two worlds: the legal or the business. With the economy shaping up the way it is more likely that businesses will be forced to cut bottom line costs through strategic planning. The easiest place to make these bottom line cuts are in utilities, i.e., turning off the water and the lights. Energy Star's partnership with the EPA has reflected this and remarked that:

“Because a strategic approach to energy management can produce twice the savings — for the bottom line and the environment — as typical approaches, EPA's ENERGY STAR partnership offers a proven energy management strategy that helps in measuring current energy performance, setting goals, tracking savings, and rewarding improvements.” (Energy Star n.d.)

In 2007 Energy Star saved businesses, organizations and consumers \$16 billion which is equivalent to avoiding the greenhouse gas emissions from 27 million cars (Energy Star n.d.). Through the promotion of facts like these hopefully the financial incentives associated with reducing excessive night lighting will be realized world-wide and the fight against light pollution will be won.

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