

# **Energy Independence and Security Act of 2007 Lighting Mandate Analysis**

An Interactive Qualifying Project Report

Submitted to the Faculty of

WORCESTER POLYTECHNIC INSTITUTE



in partial fulfillment of the requirements for the

Degree of Bachelor of Science

By

Justin Furst

Carl Haroian

Samuel Patterson

Eric Reich

Advised by Professor James C. O'Shaughnessy

February 26, 2012

# Abstract

---

When the Energy Independence and Security Act of 2007 was signed into law, the United States federal government was set to phase out energy inefficient technologies in order to pursue more energy independence and reduce carbon emissions.

One of the provisions of this law will have a very real impact on American consumers. This provision will effectively phase out all incandescent light bulbs from the consumer market by 2014. This form of regulation set off a firestorm of activism that led to showdowns in Washington D.C. This report analyzes the effects of this provision on society, the environment, and economics in-depth and presents the reader with a clear understanding of the breadth and depth of change this law would bring to the everyday lives of ordinary Americans.

# Table of Contents

---

Chapter 1: Energy Independence and Security Act of 2007.....	8
Notes About Mandates.....	10
Chapter 2: Political Opposition.....	12
Chapter 3: History of Lighting.....	16
History of Incandescent.....	18
History of Fluorescent.....	19
History of Halogen.....	20
History of LED.....	21
Chapter 4: Environmental Impact Analysis .....	22
Chapter 4.1: Manufacturing Processes.....	22
Chapter 4.1.1: Manufacturing Processes of incandescent bulbs.....	22
Chapter 4.1.2: Manufacturing Processes of fluorescent bulbs.....	24
Chapter 4.1.3: Manufacturing Processes of halogen bulbs.....	25
Chapter 4.1.4: Manufacturing Processes of LED bulbs.....	27
Chapter 4.2: Environmental impacts of materials.....	28
Chapter 4.2.1: Incandescent Bulbs Overview.....	28
Chapter 4.2.1a: Material Properties.....	29
Chapter 4.2.1b: Ecological Properties.....	30
Chapter 4.2.2: Fluorescent Bulbs Overview.....	31
Chapter 4.2.2a: Material Properties.....	31
Chapter 4.2.2b: Ecological Properties.....	31
Chapter 4.2.3: Halogen Bulbs Overview.....	32
Chapter 4.2.3a: Material Properties.....	32
Chapter 4.2.3b: Ecological Properties.....	33
Chapter 4.2.4: LED lights overview.....	33
Chapter 4.2.4a: Material Properties.....	34
Chapter 4.2.4b: Ecological Properties.....	34
Chapter 5: Generic Consumer Impact Analysis.....	35
Chapter 6: Specific Consumer Impact Analysis.....	46
Chapter 6.1: Lighting Consumption of House One.....	46
Chapter 6.2: Lighting Consumption of House Two.....	48
Chapter 6.3: Lighting Consumption of House Three.....	49
Chapter 6.4: Lighting Consumption of House Four.....	50
Chapter 6.5: CFL equivalents to Incandescent.....	50
Chapter 6.6: Savings for House One.....	51
Chapter 6.7: Savings for House Two .....	51
Chapter 6.8: Savings for House Three.....	52
Chapter 6.9: Savings for House Four.....	52
Chapter 6.10: Carbon Emissions Summary.....	52
Chapter 7: Survey Results.....	54
Chapter 7.1: Survey One: Dentist and CEO.....	54
Chapter 7.2: Survey Two: Office Manager of a Dental Office.....	55

Chapter 7.3: Survey Three: WPI Professor.....	55
Chapter 7.4 Survey Four: Second WPI Professor .....	56
Chapter 7.5: Survey Five: Father of the CEO.....	57
Chapter 7.6: Cumulative Survey Results.....	58
Chapter 8: Conclusions.....	61
Works Cited.....	64
Appendix A: Full Domestic Analysis.....	69
Appendix B: Survey Questions and Responses.....	73

# Table of Figures

---

Figure 1.1: Effects on the Light Bulb Market.....	9
Figure 2.1: CFL Bulb Cleanup.....	13
Figure 3.1: Light Bulb Market Shares in Recent Years.....	16
Figure 3.2: Incandescent Bulb.....	18
Figure 3.3: Fluorescent Bulb 1.....	19
Figure 3.4: Fluorescent Bulb 2.....	19
Figure 3.5: Halogen Bulb.....	20
Figure 3.6: LED Bulb 1.....	21
Figure 3.7: LED Bulb 2.....	21
Figure 4.1: Incandescent Bulb Diagram.....	23
Figure 5.1: Room Lighting Percentages.....	37
Figure 5.2: Consumption & Cost of Electricity of Light Bulbs.....	38
Figure 5.3: Household Electricity Consumption.....	39
Figure 5.4: Light Types and Electricity Prices.....	43

# Table of Tables

---

Table 3.1: History of Incandescent Lighting.....	18
Table 3.2: History of Fluorescent Lighting.....	19
Table 3.3: History of Halogen Lighting.....	20
Table 3.4: History of LED Lighting.....	21
Table 5.1: Fluorescent Percent of All Lighting.....	35
Table 5.2: Home effects on Lighting Consumption.....	40
Table 5.3: Assumptions Made for Comparison.....	41
Table 5.4: Case Studies of Light Bulb Electricity Costs.....	42
Table 5.5: Average Usages of Light Types.....	44
Table 6.1: Carbon Emissions Savings.....	53
Tables of Appendix A: Domestic Analysis.....	69

# Authorship

---

Chapter 1:

Author: Samuel Patterson

Checkers: Eric Reich, Carl Haroian

Chapter 2:

Author: Samuel Patterson

Checkers: Eric Reich, Carl Haroian

Chapter 3:

Authors: All members

Checkers: Samuel Patterson, Justin Furst

Chapter 4:

Author: Eric Reich

Checkers: Samuel Patterson, Justin Furst

Chapter 5:

Author: Justin Furst

Checkers: Samuel Patterson, Carl Haroian

Chapter 6:

Author: Carl Haroian

Checkers: Justin Furst, Eric Reich

Chapter 7:

Author: Carl Haroian

Checkers: Samuel Patterson, Justin Furst

Chapter 8:

Authors: All members

Checkers: Carl Haroian, Samuel Patterson

## **Chapter 1: Energy Independence and Security Act of 2007**

In 2007, President George W. Bush worked with the new Congress to try to increase American energy efficiency and strive for long-term energy independence. To pass landmark legislation to achieve these goals, political will had to be fueled by agitating factors on American voters. High gasoline and oil prices were essential to meeting the president and Congress's goals of passing legislation. There was also a strong political will to address the issue of global warming at the time. The presence of a relatively strong economy at the time allowed politicians to pursue energy efficiency legislation by appealing to the American concern for the environment <sup>1</sup>.

As part of the new Democratic Congress's 100 hour plan, they promised to pass legislation to address climate change and increase energy efficiency. A bill eventually known as the Energy Independence and Security Act (EISA) was introduced by Congressman Nick Rahall, a Democrat from West Virginia's Third District <sup>2</sup>. He was the Ranking Member of the House Resources Committee and had served in Congress since 1977. He was a believer in global warming, but also a strong proponent of coal <sup>3</sup>. He eventually became one of four Democrats who voted against the final bill. The final bill passed both houses of Congress on 18 December 2007. The bill passed the Senate 86-8 and the House 314-100 <sup>4</sup>. President Bush signed the bill as part of his "Twenty in Ten" challenge to reduce gasoline consumption 20% in ten years <sup>5</sup>.

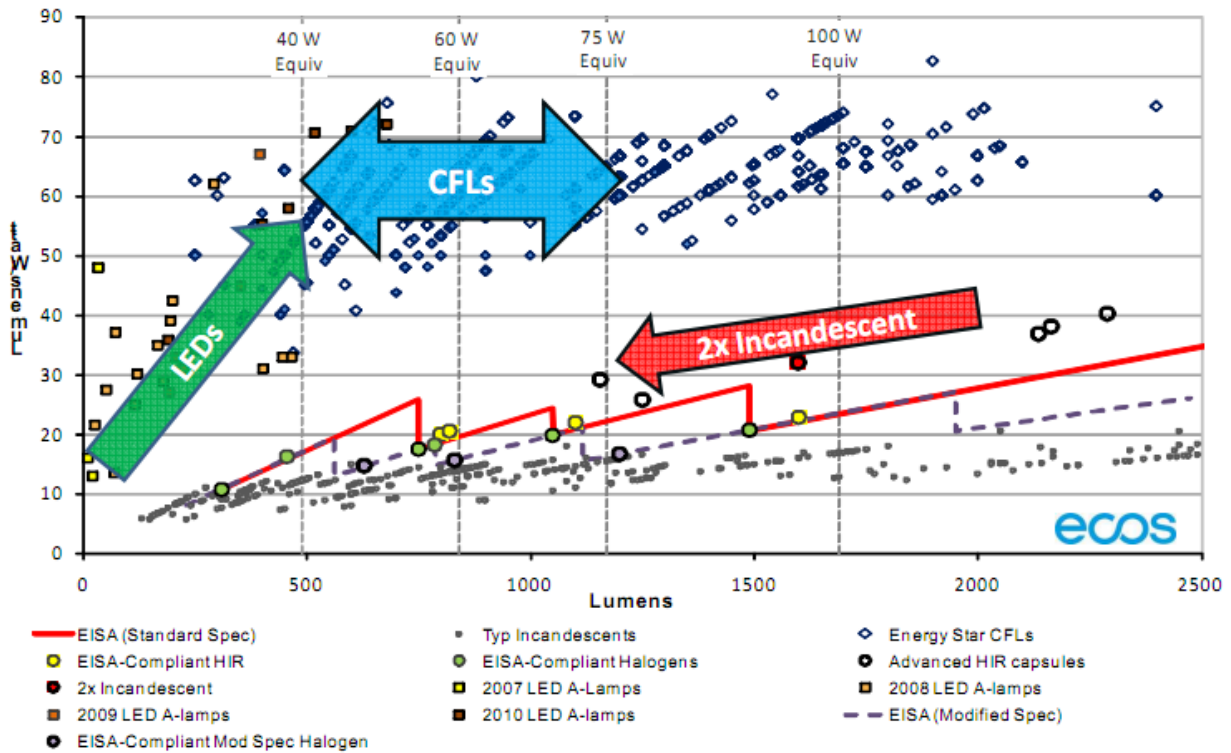
The 300+ page bill had widespread implications for American industry. It mandated CAFE standards for the government vehicle fleet of 35 miles per gallon by 2020. EISA sets renewable fuel standards at 9 billion gallons of yearly production in 2008 and mandates renewable fuel production to increase to 36 billion gallons by 2022. The bill also aims to increase the efficiency of buildings, products, and vehicles and promote research on greenhouse



gas capture. Perhaps the most obvious implications from the perspective of an American citizen are those of the mandated efficiency standards for buildings. Part of these standards is the mandated increase in lighting efficiency <sup>6</sup>.

The focus of this report will be on these lighting standards. EISA aims to increase lighting efficiency in buildings by 30%. Starting 1 January 2012, Americans will no longer be able to produce or import 100 Watt (W) light bulbs unless they are 30% more efficient. However, it will still be legal to use and sell existing 100W bulbs. In effect, this will permanently ban 100W incandescent light bulbs that many Americans enjoy. This is because the current incandescent light bulb model presents little room for improvements in efficiency. The next phase of the lighting efficiency standards agenda starts 1 January 2013, when the same standards are applied to 75W bulbs. Ultimately, on 1 January 2014, these standards are applied to 60W and 40W bulbs <sup>7</sup>.

Efficiency (lumens/W) vs. lumens rating <sup>33</sup>



**Figure 1.1** – The red jagged line represents the threshold EISA is projected to set for domestic lighting efficiency. The intent is to phase out all less-efficient bulbs below that red line, which typically happen to be incandescent bulbs.

**Notes about the mandates**

Bulbs that will still be available include most compact fluorescent (CFL) fixtures, halogen fixtures, and LED fixtures. There are twenty-two types of special bulbs that are exempt from the regulations as well, listed below:

1. Appliance lamps
2. Black light lamps
3. Bug lamps
4. Colored lamps
5. Infrared lamps
6. Left-hand thread lamps
7. Marine lamps
8. Marine’s signal service lamps
9. Mine service lamps
10. Plant light lamps

11. Reflector lamps
12. Rough service lamps
13. Shatter-resistant lamps (including shatter-proof and shatter-protected)
14. Sign service lamps
15. Silver bowl lamps
16. Showcase lamps
17. 3-way incandescent lamps
18. Traffic signal lamps
19. Vibration service lamps
20. G-shape lamps with a diameter of 5" or more
21. T-shape lamps that use no more than 40W or are longer than 10"
22. B, BA, CA, F, G16-1/2, G-25, G-30, M-14, or S lamps of 40W or less <sup>32</sup>

If consumers want to use light bulbs that are capable of dimming, they must use halogen or LED lighting, or if they want to use CFL bulbs, they must consult the product label to see if the device is compatible with dimmers. CFL bulbs do not typically dim as well as other types of bulbs, but ones that dim are available on the market <sup>32</sup>.

## Chapter 2: Political Opposition

Within just two years, most Americans will soon no longer be able to use traditional incandescent light bulbs in their homes. This development has caused quite a bit of political backlash, mostly among those who favor less active government. Opponents of the light bulb mandates contend that the bill intrudes on American consumers and businesses. They argue that the bill is a power grab outside the bounds of federal power under the Constitution. In July 2011, the U.S. House of Representatives voted on the Better Use of Light Bulb (BULB) Act. It was introduced by Congressman Joe Barton, a Republican from Texas. The bill failed 223-193, since repeals require a two-thirds majority to pass<sup>8</sup>. Congresswoman Michele Bachmann, a Republican from Minnesota, also introduced a repeal bill called the Light Bulb Freedom of Choice Act, which is currently in committee<sup>9</sup>. Along with these legal efforts, many media figures and commentators have raised the topic, calling it an outrage and urging their viewers and listeners to take action.

Recently, Virginia House of Delegates member Bob Marshall, who is running for the United States Senate, proposed a bill to allow manufacture and sale of incandescent light bulbs within Virginia borders. This would directly conflict with EISA if passed. When state-level bills conflict with federal law, the federal government can sue the state in question, which can lead to a high-level court decision. However, Virginia's own Attorney General Ken Cuccinelli believes that EISA's Constitutionality is not in question. This argument will undoubtedly continue, as seven other states have pending legislation dealing with this issue, and Texas has already passed a similar bill to that of Bob Marshall<sup>31</sup>.

Marshall contends that aside from being a violation of the 10<sup>th</sup> Amendment (which states that all powers not granted to the federal government are left to the states and the people), EISA

is a safety issue. Marshall specifically cites the fact that fluorescent light fixtures contain mercury, which is a neurotoxin in humans<sup>31</sup>. This is a common concern among opponents of this bill. The Environmental Protection Agency has a standard procedure for CFL bulb cleanup, shown below in an image taken from their website. They explain that the mercury in a typical CFL bulb is less than 1/100<sup>th</sup> of the mercury in a thermometer and that the cleanup instructions are merely a precaution, not a cause for emergency.

### **Before Cleanup**

- Have people and pets leave the room.
- Air out the room for 5–10 minutes by opening a window or door to the outdoor environment.
- Shut off the central forced air heating/air-conditioning system, if you have one.
- Collect materials needed to clean up broken bulb:
  - stiff paper or cardboard;
  - sticky tape;
  - damp paper towels or disposable wet wipes (for hard surfaces); and
  - a glass jar with a metal lid or a sealable plastic bag.

### **During Cleanup**

- **DO NOT VACUUM.** Vacuuming is not recommended unless broken glass remains after all other cleanup steps have been taken. Vacuuming could spread mercury-containing powder or mercury vapor.
- Be thorough in collecting broken glass and visible powder.
- Place cleanup materials in a sealable container.

### **After Cleanup**

- Promptly place all bulb debris and cleanup materials outdoors in a trash container or protected area until materials can be disposed of properly. Avoid leaving any bulb fragments or cleanup materials indoors.
- If practical, continue to air out the room where the bulb was broken and leave the heating/air conditioning system shut off for several hours.

### **Figure 2.1: CFL bulb cleanup<sup>34</sup>**

While some Americans remain committed to reversing the lighting mandates, others are gearing up for the change. Some suppliers of light bulbs are stocking up on incandescent light bulbs ahead of the upcoming deadlines<sup>8</sup>. Light Bulb distributors have begun taking measures to display the luminescence of their products on their packaging, calling their products “X Watt

equivalent” – where X represents the amount of Watts a certain type of incandescent light bulb is classified by. For example, a manufacturer may sell a 20W fluorescent light bulb marketed as “75W equivalent,” which means the 20W bulb produces about the same amount of light intensity as a 75W incandescent bulb. Manufacturers and distributors have also begun displaying the amount of light intensity in absolute terms, in terms of “lumens” – so consumers will be making their purchasing decisions based on the amount of light intensity emitted, rather than the amount of energy the bulb consumes <sup>10</sup>.

The most recent \$1 trillion stopgap budget measure passed by the House of Representatives included language that has nullified the standards included in the Energy Independence and Security Act by de-funding them. This prevents the Department of Energy from implementing the rules until 30 September 2011 <sup>28</sup>.

Companies involved in lighting are frustrated that the GOP has blocked the standards. This is because they have made preparations for the new regulations, and invested millions of dollars in changing their operations. The National Electrical Manufacturers Association has been lobbying the GOP for over a year in an effort to convince them to allow the regulations to take hold. The GOP has sided with angry consumers over industry, however <sup>29</sup>.

“‘The American people don’t like being told what to do,’ said Thomas Schatz, president of the Council for Citizens Against Government Waste, which has lobbied Congress on the issue. ‘I’m glad I get to keep my light bulbs.’” Other Conservative groups such as Freedom Works, Americans for Prosperity, and the National Taxpayers Union opposed the Act as well <sup>29</sup>.

The Lupus Foundation of America lobbied both chambers of Congress on the issue, because lupus patients respond poorly to fluorescent lighting. They argue that lupus patients would suffer if incandescent light bulbs were harder to buy. More than 36 organizations filed

disclosures for lobbying on light bulbs just in 2011, while just three were filed between 2007 and 2010. This shows that the mandates were initially acceptable, but long-term planning made last-minute changes more onerous than the initial mandates <sup>29</sup>.

Jack Gillis of the Consumer Federation of America said “the [spending bill] cut funding for enforcement, however the law is still in effect” and that he expects companies to comply with the law. Steven Nadel, executive director of the American Council for an Energy-Efficient Economy said that the major manufacturers have already taken all the steps to follow the law. He said that GOP efforts to block enforcement “are probably not going to have much of an impact” <sup>30</sup>.

Experts say that companies will comply with the law despite efforts to block enforcement. This is because the companies have already taken costly steps toward compliance, and reversing the trend would cost more than continuing on the path toward compliance <sup>30</sup>.

## Chapter 3: History of Lighting

To better understand what impacts the Energy Independence and Security Act of 2007 will have, we must understand the lighting industry's history. Over the past two hundred years, lighting has made great progress. It is likely that we will see further progress in the lighting industry toward higher efficiency, longer life cycles, and lower prices. Lighting was not nearly universal until the middle of the 20<sup>th</sup> Century. Since then, Americans have become highly dependent on light bulbs in their homes and offices. Something that even hints at disrupting business as usual in the lighting industry clearly had the potential to anger many Americans who like the status quo on lighting and as the previous chapter shows, it did.

Incandescent light bulbs have dominated the American lighting industry for over 100 years. Only recently have other types of bulbs become significant market forces. This is mostly because they are more efficient, and therefore tend to cost less money in the long run. Below is a chart which shows the American light bulb market share since 2002, showing a growth in CFLs:

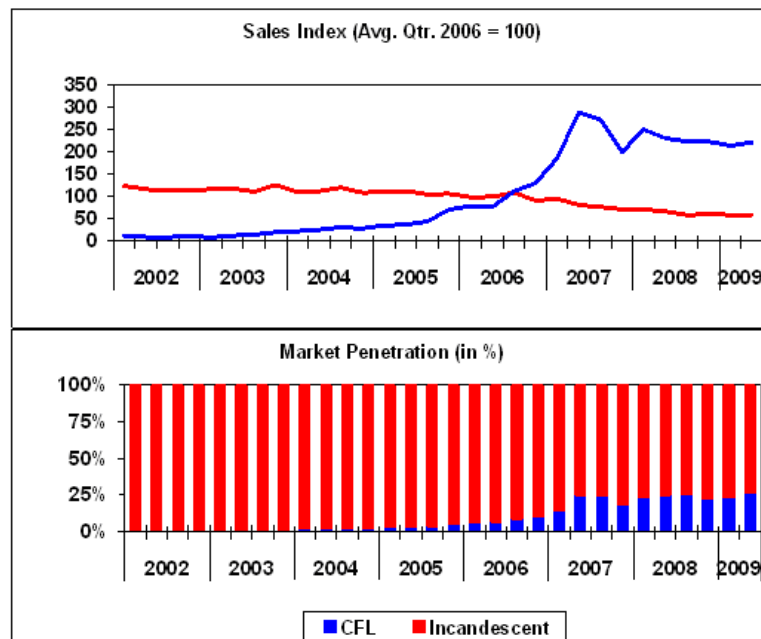


Figure 3.1: Light bulb market share in recent years <sup>27</sup>



Compact fluorescent light bulbs have rapidly increased market share in recent years, to 26% in 2009. Halogen and LED lighting make up a miniscule market share in terms of domestic lighting. The transition to CFL domestic light bulbs as outlined in this chart is even more interesting because this chart shows the years preceding the upcoming regulations. It appears that Americans had been moving toward CFL lighting based on financial benefit, rather than government coercion. One thing this can demonstrate is that the transition away from incandescent light bulbs will be increasingly easier for Americans to cope with.

Below are charts outlining the histories of the four best-selling types of domestic light bulbs: incandescent, fluorescent, halogen, and light-emitting diode (LED). Incandescent bulbs have been around far longer than the other types. This contributes to the notion that they are part of the status-quo and Americans are used to them. At the same time, the newer technologies are bound to become more affordable and efficient because they have only begun being viable products in more recent years. For example, LED lighting only achieved a luminosity of 300 lumens as recently as 2008.

## Incandescent



**Figure 3.2:** incandescent medium base light bulb

Source: [http://www.lightbulbmarket.com/product/049471\\_100-Watt-130-Volt--A-19-Philips-Light-Bulb](http://www.lightbulbmarket.com/product/049471_100-Watt-130-Volt--A-19-Philips-Light-Bulb)

1809	The first electric light is invented by the English chemist Humphrey Davy. This was called a carbon arc lamp, by connecting a battery to two wires and attaching a charcoal strip between the wires. <sup>11</sup>
1840	Warren De La Rue encloses a platinum filament in a vacuum tube and passes a current through it. This design was inefficient because of the high cost of platinum. This was the first known incandescent light bulb. <sup>12</sup>
1841	Fredrick Moylens is granted the first patent for an incandescent lamp. <sup>13</sup>
1872	Russian inventor Alexander Lodgyin obtains patents for several incandescent light bulbs, using a variety of metals for filaments. <sup>14</sup>
1874	Henry Woodward and Matthew Evans design a carbon-filament light bulb filled with nitrogen gas. Patent is eventually sold to Thomas Edison. <sup>12</sup>
1870s	Joseph Swan perfects the carbon-filament bulb, improving efficiency and bulb lifetime. <sup>12</sup>
1878	Edison develops the first commercially viable carbon-filament light bulb. <sup>12</sup>
1910	General electric commercializes the manufacture of tungsten light bulbs. <sup>12</sup>

**Table 3.1:** History of incandescent light bulbs

We see that the incandescent light bulb has a roughly 200 year history, which makes it the established light bulb choice for consumers. However, the bulbs have really only been on the consumer market for about 100 years. Its technology is tried and true, but it cannot be improved upon as easily anymore because most of the feasible improvements have been made.

## Fluorescent



**Figure 3.3 and 3.4:** Compact fluorescent (CFL) light bulbs, one curly, one more pleasing design  
 Source (left): <http://www.istockphoto.com/stock-photo-6051559-compact-fluorescent-light-bulb.php>  
 Source (right): <http://www.thedailygreen.com/green-homes/latest/new-cfl-bulbs-46010808>

1857	Alexandre Becquerel theorized the idea of putting fluorescent light into tubes. He performed experiments coating electric discharge tubes with luminescent materials, a process that would later be used to develop fluorescent lights. <sup>15</sup>
1901	Peter Cooper Hewitt patented the first mercury lamp in 1901 (US patent #889,692). First prototype of today's modern fluorescent lights. <sup>15</sup>
1927	Edmund Germer invented a much higher pressure lamp. He is said to be the inventor of the first true fluorescent bulb. He patented the first experimental fluorescent lamp. <sup>15</sup>
1936	On November, 23, 1936 fluorescent bulb lit the large banquet hall celebrating the 100 <sup>th</sup> anniversary of the US patent office. <sup>16</sup>
1938	In 1938, the 14 Watt, 15 inch 1-1/2" MAZDA lamp was introduced. Fluorescent lighting was now flourishing, and very popular. <sup>16</sup>
1938	The first viable fluorescent lamp was invented by George Inman and a group of General Electric scientists who had been researching fluorescent lighting prior to their invention. They bought the patent rights from Edmund Germer. <sup>15</sup>
1938	GE began selling fluorescent lighting to the public. <sup>16</sup>

**Table 3.2:** History of fluorescent lighting

Fluorescent lighting has a briefer history than incandescent lighting, of about 150 years. However, the lamps have only been in the broader consumer market since 1938, making the history actually briefer than one might think. The technology has been established for a long time, which raises questions about why the bulbs are not more popular. This comes down to lighting quality, cost, safety concerns, and other topics which are addressed in this report.

## Halogen



**Figure 3.5:** Halogen light bulb

Source: <http://www.elightbulbs.com/Westinghouse-36304-75R30FL-SL-R30-Halogen-Light-Bulb>

1955	Elmer Fridrich and Emmet Wiley created the first halogen lamp with GE. Others had tried to do it in the past but couldn't because they couldn't prevent the blackening of the lamp. <sup>18</sup>
1959	Elmer Fredrich and Emmett Wiley invented the first tungsten halogen lamp. <sup>17</sup>
1960	A better one was invented by Fredrick Moby, a GE engineer, which could fit into a standard light bulb socket. <sup>17</sup>
1992	United States passed the National Energy Security Act, mandating the use of advanced bulbs that were more efficient. <sup>17</sup>
1997	In mid-1997, the Consumer Products Safety Commission coordinated a recall of halogen lamps for in-home repair due to the fire hazards caused by poor fixture design and hot bulbs. <sup>17</sup>

**Table 3.3:** History of halogen lighting

Halogen lamps have existed for about 55 years. This is much newer than the more established incandescent and fluorescent lamps. Notice that some lamps were recalled in 1997 due to fire hazards. This is evidence of the fact that these bulbs are not well established yet, and could see technological improvements in the near future.

## LEDs



**Figure 3.6 and 3.7:** LED light fixtures, unidirectional and omnidirectional, respectively.

Source (left): [http://www.lampsplus.com/products/warm-white-6-watt-non-dimmable-led-light-bulb\\_\\_u8222.html](http://www.lampsplus.com/products/warm-white-6-watt-non-dimmable-led-light-bulb__u8222.html)

Source (right): <http://www.oogalights.com/LED-S14-Light-Bulb-Medium-Base-Faceted-Bulb-Cool-White.aspx>

1907	Electroluminescence is discovered by H.J Round. <sup>19</sup>
1927	Oleg Vladimirovich Losev reports the creation of the LED. <sup>20</sup>
1955	Infrared emission is reported from several semiconducting materials, including Gallium Arsenide. <sup>21</sup>
1961	Gary Pittman and Robert Blard are granted a patent for an infrared GaAs LED. <sup>22</sup>
1962	Nick Holonyak, Jr. invents the first visible spectrum LED. <sup>23</sup>
1972	M. George Craford invents the first yellow LED. <sup>23</sup>
1976	T.P. Pearsall invents LEDs usable in optical telecommunications. <sup>24</sup>
1995	Alberto Barbieri runs experiments on high brightness blue LEDs (invented by Shuji Nakamura). <sup>25</sup>
2008	A luminosity of 300 lumens was achieved by using nanocrystals. <sup>26</sup>

**Table 3.4:** History of light emitting diodes (LEDs)

The technology for LEDs is about 100 years old, but LED bulbs only reached a decent level of lighting capacity (lumens) as recently as the 21<sup>st</sup> century. These bulbs are new and different, but opportunities for improvement in quality and cost are certainly there.

## **Chapter 4: Environmental Impact Analysis**

In order to understand the environmental impact of the Energy Independence and Security Act of 2007, it is necessary to compare the environmental impact caused by the fabrication of incandescent bulbs to that of alternative types of bulbs, namely, halogen, fluorescent, and LED. Each step involved in the manufacturing of a bulb requires the use of energy, and generates a carbon footprint. In order for the Energy Independence and Security act to have a positive impact on the environment, the alternatives to incandescent bulbs must be efficient enough to make up for any increased energy use in manufacturing processes.

In this chapter, the manufacturing process for incandescent bulbs, fluorescent bulbs, LED lights, and halogen bulbs are described in detail. Following this, an environmental impact analysis is carried out for each material involved in the fabrication of each type of bulb, using CES Edupack software to obtain the relevant figures for carbon footprint and embodied energy.

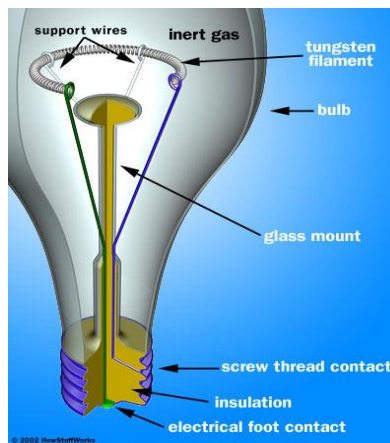
### **4.1: Manufacturing Processes for Different types of light bulbs**

#### **4.1.1: Incandescent Light bulb**

The main component of an incandescent bulb is the tungsten filament. The filament is prepared by mixing the tungsten with another material, known as a binder, and then pulling through a small orifice, called a die, to make the tungsten-binder mixture into a thin wire. This wire is then wound around a steel rod, referred to a mandrel. The tight winding of the wire allows a larger amount of tungsten filament to be fit inside a single bulb. Once the wire is wound, the wire and mandrel are heated to temperatures up to 4,500 degrees Fahrenheit, and the mandrel is dissolved with acid. This process is referred to as annealing. The coiled tungsten wire is then attached to lead-in nickel-iron wires via spot-welding or pressing onto the filament<sup>35 36</sup>.

The glass casing itself is produced using a ribbon machine. In the ribbon machine, glass is heated, then moved along a conveyor belt in a long ribbon. The heated glass is blown by nozzles placed along the conveyor belt, and into molds in the shape of the bulb casing. The bulb casings for incandescent bulbs are typically made from soda lime glass. The bulbs are cut from the ribbon, and the inside of the casing is coated with silica, which serves to reduce the glare produced by the filament when the light is in operation. The bases, made of aluminum, are also fabricated using a mold.<sup>35 36</sup>.

The completed bulb, base, and filament are assembled by machines. The filament is inserted into the bulb, and any gas present in the bulb is removed, in a process referred to as evacuation. The air is removed to help preserve the life of the filament by slowing oxidation. A mixture of inert noble gases, such as argon and neon, are then pumped in. This serves to increase the lifetime of the filament. The base is then attached to the rest of the light, with the lead-in wires touching the base to allow the conduction of electricity<sup>35 36</sup>.



**Figure 4.1: Incandescent Light Bulb Diagram**

Source: <http://home.howstuffworks.com/light-bulb1.htm>

### 4.1.2 Fluorescent Light Bulb

The fabrication of fluorescent light bulbs has four main steps. The first is the fabrication of the mount. A mount is the piece of the lamp that connects the filament to the base of the fixture. There are three machines used in the fabrication of mounts. First, a flare making machine turns glass into flares, which is then separated from the glass and polished by use of a flame. The flares, as well as exhaust tubes and lead-in wires, are fed into a stem-making machine, which then forms the stems. These stems are fed into a mounting machine, where they are attached to tungsten wire filaments.

Next is the fabrication of the glass tube that houses the filament. Glass tubes are placed in a washing and coating machine. The glass is washed and dried, and is then coated with fluorescent powder, usually made of phosphorous, on its inner walls. The tubes are unloaded onto a conveyor belt, which transports them through an oven, followed by a cooling chamber. This bakes the fluorescent coating onto the tube. The coating is removed from the ends of the tubes via end-cleaning machines. The tubes are then transported to the sealing machine for the final steps of the assembly.

Following this step is the base fabrication. The components of the base are fed into a machine, and a sealing compound is dispersed via the use of a filling machine. The bases are sent to the basing machine.

The final step is the sealing of the base onto the rest of the bulb. The mounts are fed into the sealing machine and attached to the glass tubes. An exhausting machine evacuates the glass tube, removing any air. A small amount of mercury is injected, followed by a filler noble gas, such as argon, neon, or xenon. The exhausted tubes are attached to the bases in a basing machine, and heated by a gas burner. Filled caps are attached to the end of each tube, completing



the process.<sup>37</sup>

### **Adverse Health Effects from Mercury in CFL Bulbs**

As mentioned in the previous section, CFL bulbs contain a small amount of mercury, which is used to generate ultraviolet (UV) light output. CFL bulbs make use of elemental mercury, which, in the event of a broken bulb, can be inhaled as a vapor, which is absorbed through the lungs.<sup>38 39 40</sup>

Typically, the severity of the symptoms experienced from mercury poisoning depend on the dosage, age of the victim, length and method of exposure, and existing health of the victim. Children are at a higher risk for adverse health effects due to mercury exposure than adults. Some symptoms of elemental mercury poisoning include tremors, mood swings, irritability, insomnia, weakness, muscle atrophy, headaches, and impairment of cognitive function. High levels of exposure may lead to kidney damage, respiratory failure and death.<sup>38 39 40</sup>

There are about 4 milligrams of mercury in an average CFL bulb. A spill of 500mg is considered to be small, and some CFLs may contain even less mercury than this – possibly as low as 1.5 – 2.5 milligrams. Due to the very small amounts of mercury present in CFLs, there should not be any adverse health effects from broken bulbs, and should not present any environmental problems, provided that broken bulbs are disposed of properly. Proper procedure for the disposal of broken fluorescent bulbs is outlined in chapter 2.<sup>38 39 40</sup>

#### **4.1.3: Halogen Bulbs**

The manufacturing process for halogen lights is similar to that of incandescent lights bulbs, with a few key differences. The tungsten filament is wound around a cylindrical rod, as a

straight filament has poor emission characteristics. There are a few other varieties of filaments, including flat filaments, which are wound around rectangular rods, and double filaments, in which a cylindrical filament is wound around a cylindrical rod, and the wound filament is wound again.<sup>41</sup>

The bulb itself is made of fused quartz glass. A glass tube is cut to the correct length, and an exhaust tube is attached. To accomplish this, the top of the tube is heated, and a tungsten carbide wheel folds the glass to form a dome with a hole. A small glass exhaust tube is placed in the hole and joined by heating. This tube is used to remove air from the bulb and introduce the filler gas.<sup>41</sup>

Next, the mount is made. The bridge is composed of tungsten wires embedded in a quartz rod, which is welded to the support wires, and to the outer lead assembly, which is made of molybdenum sealing foils. It is then sent through a hydrogen furnace at 1925 Fahrenheit, to remove oxides that may damage the tungsten filament. The mount is hermetically sealed in the bulb by a press. It is inserted into the bottom of the bulb, which is heated to 3272 Fahrenheit, to soften the quartz, and stainless steel pads press the quartz to the molybdenum foils making up the seal. An inert gas is pumped in to prevent the mount from oxidizing.<sup>41</sup>

Following this, the bulb is filled with a halogen gas mixture. There is a high pressure in the lamp, which is achieved by filling the lamp to above atmospheric pressure, then cooling it in liquid nitrogen to condense the halogen mixture to a lower pressure. The exhaust tube is then melted to lock the gas mixture inside the bulb. The finished lamp is then attached to the base, using special cement.<sup>41</sup>

#### 4.1.4: LED Lights

A typical LED light consists of four main components: a circuit board, a heat sink, a power supply, and a shell. The lights begin as PCBs and LED elements from specialized factories.<sup>42</sup>

The PCB is made from a thin sheet of aluminum, which is coated with a non-conductor, and conducting copper lines are traced to form the circuit. LED elements are then soldered on to the board. Most PCBs for LED lights are circular; so many PCBs are combined into one large rectangle to allow for automated soldering. Then, the PCBs are split apart, and passed through a re-soldering over to melt the soldering paste.<sup>42</sup>

The PCBs are then sent to a dual in-line package assembly line. Workers manually add components to the PCB, such as integrated chips or an internal small power supply. The PCB is then attached within a heat sink, which is necessary due to the heat generated by the LED elements. The power connector board is attached with an adhesive. The small power supply reduces the incoming main power to a lower voltage.<sup>42</sup>

The shell for an LED lamp is made of plastic. It covers the power supply and is connected to the PCB and heat sink. Holes are punched into the plastic to facilitate the escape of hot air. Wires are soldered for the bulb socket and the shell is attached to the rest of the PCB.<sup>40</sup>

The LED bulbs are then sent to quality control, in which the bulb is powered on and burned in for 30 minutes. The LEDs are also tested for voltage leaks, power consumption, and efficiency. Following this, the metal socket base is crimped in place. The bulbs are then labeled, packaged, and shipped.<sup>42</sup>

## **4.2: Environmental aspects and Composition**

This section discusses the environmental impact of the main components of each kind of bulb. This is given in terms of the embodied energy (amount of energy required in a given manufacturing step) and the CO<sub>2</sub> footprint (the amount in pounds of carbon dioxide produced per pound of the given material produced). In this section, a brief overview of each material function in the bulbs is given. Following this, numerical values for CO<sub>2</sub> footprint and embodied energy is given. The software CES Edupack was used to obtain the numerical values given in this section.

### **4.2.1: Incandescent Bulbs.**

The main materials in incandescent bulbs are tungsten, soda lime glass, nickel-iron wire, aluminum, and noble gases. Tungsten is used in the filament of the light bulb due to its high melting point, which allows it the filament to operate at high temperatures. The high temperatures occur because the resistance of the tungsten is so high that the power is dissipated as light. This is essentially how light bulbs work. Soda lime glass is used in the casing of the bulb to aid the photo effect. Nickel alloy wire is used in the lead-in wires that connect to the tungsten filament.

Incandescent bulbs work by allowing an electrical current to flow through the lead-in wires into the tungsten filament. Free electrons flow through the metal and collide with tungsten atoms, increasing their energy temporarily. This causes electrons bound to the tungsten atoms to move to a higher energy level, or valence electron shell. The energy level of the atom then falls back to normal, and the electrons in an elevated energy state emit a photon as they fall to a lower energy state.<sup>43</sup>

#### 4.2.1a: Material Properties

The filaments in incandescent bulbs are typically made of pure tungsten. Pure Tungsten has a melting point between 5790 and 6170 Fahrenheit, which makes it difficult to process, but useful in incandescent bulbs. Its high melting point gives it creep resistance up to 1400 Celsius. The service temperature for tungsten is between 2460 and 2550 Fahrenheit. It is a good thermal conductor, with a thermal conductivity of between 57.8 and 82 BTU-ft/h-ft<sup>2</sup>-F. Tungsten is also a good electrical conductor.<sup>43</sup>

Incandescent bulbs also contain soda lime glass, which is used in the bulb casing. Soda lime is a composite of several other materials. It typically contains 1% Alumina (Al<sub>2</sub>O<sub>3</sub>), 5% Calcia (CaO), 4% Magnesia (MgO), 17% Sodium Oxide (Na<sub>2</sub>O), and 73% Silica (SiO<sub>2</sub>).<sup>43</sup>

Incandescent light bulbs also make use of nickel alloys and aluminum. Aluminum (Al) is typically used as an alloy. Some elements that alloy with aluminum include magnesium, copper, zinc, and lithium. Aluminum costs between 156 and 181 USD per pound. It is a good conductor of electricity.<sup>43</sup>

Like aluminum, Nickel is also used as an alloy in incandescent bulbs. Nickel has a high melting point, 1450 Celsius, which makes it a good material for the lead-in wires in incandescent bulbs. Typically, nickel forms an alloy most commonly with chromium and aluminum. The alloy may contain as much as 30% of these two elements. Nickel costs between 17.5 and 19.2 USD per pound. It is a good thermal conductor, with thermal conductivity between 38.7 and 52.6 BTU-ft/hr-ft<sup>2</sup>-F, and is also a good electrical conductor.<sup>43</sup>

#### 4.2.1b: Ecological Properties

Tungsten typically costs between 10.1 and 11.1 USD per pound. It has an embodied energy between 33900 and 37500 kcal per pound of tungsten used, a CO<sub>2</sub> footprint between 19.7 and 21.8 pounds of CO<sub>2</sub> produced per pound of tungsten produced, and is recyclable.

Soda lime has an embodied energy between 1480 and 1640 kcal per lb soda lime produced, and CO<sub>2</sub> footprint between .738 and .816 pounds of CO<sub>2</sub> per pound of soda lime produced. The production of soda lime requires the usage of between 399 and 440 cubic inches of water per pound of soda lime produced. The energy required for the glass molding process is between 891 and 895 kcal per pound of molded glass produced. The glass molding generates a CO<sub>2</sub> footprint between 0.648 and 0.727 pounds of CO<sub>2</sub> per pound of molded glass produced. Soda lime is recyclable, and the recycling process has an embodied energy between 651 and 791 kcal per pound of soda lime recycled, and a CO<sub>2</sub> footprint between 0.324 and 0.359 pounds of CO<sub>2</sub> per pound of soda lime recycled.

For primary production, Nickel requires an embodied energy between 13800 and 15200 kcal per pound of nickel produced, which generates a CO<sub>2</sub> footprint between 7.89 and 8.82 pounds of CO<sub>2</sub> per pound of nickel produced. Aluminum has an embodied energy between 21700 and 25800 kcal per pound of aluminum produced, which generates a CO<sub>2</sub> footprint between 11.2 and 13.1 pounds of CO<sub>2</sub> per pound of aluminum produced. This requires the usage of between 3460 and 10400 cubic inches of water per pound of aluminum produced. The casting of aluminum into molds also requires energy – aluminum has a casting energy between 1200 and 1320 kcal per pound of aluminum casted, which generated a CO<sub>2</sub> footprint between 0.829 and .0916 pounds of CO<sub>2</sub> per pound of aluminum. Both aluminum and nickel are recyclable.

### **4.2.2: Fluorescent Bulbs**

Fluorescent bulbs contain some of the same materials as incandescent bulbs. Both make use of soda lime, aluminum, and tungsten. However, fluorescent bulbs generate electricity using a method different than that of incandescent bulbs. In incandescent bulbs, light is generated as a result of heat caused by free electrons colliding with tungsten atoms. Light in fluorescent bulbs is created via a chemical reaction. A current is sent through the lamp, and passes through an electrode, which has a tungsten filament. The energy generated by electrons flowing across the cathode causes liquid mercury present in the tube to change into a gas. This excites the electrons in mercury, causing them to be in an excited energy state. Upon falling back to a lower energy state, they release a photon. The photons released by this process are in the UV range, outside of human vision. However, the inside of the bulb is coated with phosphor powder, which glows with a visible light when excited by the photons from the mercury.<sup>44</sup>

#### **4.2.2a: Material properties**

Fluorescent bulbs make use of many of the same materials as incandescent bulbs, such as nickel, aluminum, and soda lime glass. These properties can be found in section 4.2.1(a) and (b), and will not be listed again here.<sup>44</sup>

Liquid mercury is found in the tubes of fluorescent bulbs. Fluorescent bulbs use commercial purity liquid mercury, which is composed of about 99.99% mercury. Mercury costs between 2.35 and 7.05 USD per pound. It has a melting point of -38.2 Fahrenheit.<sup>44</sup>

#### **4.2.2b: Ecological properties**

Primary production of liquid mercury requires an embodied energy between 18300 and

20300 kcal per pound of mercury produced. This generates a CO<sub>2</sub> footprint between 10.6 and 11.8 pounds of CO<sub>2</sub> per pound of mercury produced. Liquid mercury is recyclable. The embodied energy for recycling of mercury is about 404 kcal per pound, and generates a CO<sub>2</sub> footprint between 0.212 and 0.235 pounds of CO<sub>2</sub> per pound of mercury recycled.

### **4.2.3: Halogen Bulbs**

Halogen bulbs share many similarities with incandescent bulbs, and function in a very similar manner. Both make use of a glass casing, an aluminum base, and a tungsten filament. However, fused quartz glass is used in halogen bulbs, as opposed to soda lime glass. This is due to fused quartz glass's ability to tolerate higher temperatures than soda lime, which is necessary due to the high temperatures that halogen light bulbs operate at. Halogen bulbs also tend to use heavier noble gases as a filler when compared to incandescent or fluorescent bulbs. They also contain a small amount of a halogen gas, such as chlorine, bromine, or fluorine, in addition to the filler. This improves the lifetime of the bulb, as a consequence of a process known as the tungsten cycle. When tungsten evaporates due to the heat of operation, halogen gas reacts with the escaped tungsten atoms, resulting in the atoms being deposited back on the tungsten filament.<sup>45 46</sup>

#### **4.2.3a: Material Properties**

Halogen lights are very similar to incandescent lights, having only a few differences in materials used. The first is the replacement of soda lime glass with silica glass. Silica is composed of 99.9 percent silicon oxide (SiO<sub>2</sub>) and costs between 2.82 and 4.7 USD per pound. Silica glass has a maximum service temperature between 2010 and 2550 Fahrenheit, which



prevents it from melting when exposed to the levels of heat produced by halogen bulbs.<sup>45 46</sup>

#### **4.2.3b: Ecological Properties**

Primary production of silica glass requires an embodied energy between 3240 and 3580 kcal per pound of silica produced. This generates a CO<sub>2</sub> footprint between 1.61 and 1.78 pounds of CO<sub>2</sub> per pound of silica produced, and requires the usage of between 2120 and 6370 cubic inches of water per pound of silica.

The molding of silica requires between 2240 and 2470 kcal of energy per pound of silica, and generates a CO<sub>2</sub> footprint between 1.66 and 1.82 pounds of CO<sub>2</sub> per pound of silica. Silica is recyclable, requiring an embodied energy between 1420 and 1570 kcal per pound, and generating a CO<sub>2</sub> footprint between 0.708 and 0.782 CO<sub>2</sub> per pound of silica recycled.

#### **4.2.4: LED Lights**

The essential component of these LED elements is gallium arsenide, a semiconducting material. GaAs is synthesized by mixing gallium and arsenic in a solution covered by boron oxide. A metal rod is then inserted into the GaAs solution, and crystals are allowed to grow on the rod. The solid GaAs crystals are then removed from the rod when sufficient crystal growth has occurred.<sup>47 48</sup>

Following this, the GaAs crystals are sliced into very thin wafers, as small as half a micron. Light is generated when electrons move from one wafer to another, which happens due to differing electron densities between neighboring wafers. The more positively charged wafer has positively charged holes, which serve as openings for free electrons, and the more negatively charged wafer has extra free electrons.<sup>49</sup> This difference is achieved by a process called doping.

Doping adds electrons to the GaAs wafers to allow them to conduct electricity. Typically, this is done by adding silicon, zinc, nitrogen, or germanium.<sup>50</sup>

One other important material in LED lights is epoxy. Epoxy is a non-conductor, which is used to coat the aluminum PCB.

#### **4.2.4a: Material Properties**

Epoxy is a type of glass filler. It costs between 1.49 and 1.64 USD per pound. Its composition is a combination of a polymer and glass – between 60 and 80 percent epoxy resin, and between 20 and 40 percent glass filler. It has a resistivity of between  $10^{20}$  and  $10^{21}$  milliohms, which makes it useful as a non-conducting material to cover the aluminum PCB board.<sup>47 48</sup>

#### **4.2.4b: Ecological Properties**

Primary production of epoxy requires an embodied energy between 10700 and 15300 kcal per pound of epoxy produced. This generates a CO<sub>2</sub> footprint between 4.17 and 4.61 pounds of CO<sub>2</sub> per pound of epoxy produced. Molding of epoxy into a suitable shape to cover the PCB also requires energy – between 2330 and 2570 kcal per pound, which generates a CO<sub>2</sub> footprint between 1.72 and 1.89 pounds of CO<sub>2</sub> per pound of epoxy. Epoxy is not recyclable, but can be burnt to recover energy, requiring between 1300 and 1370 kcal per pound of epoxy and generating between 0.968 and 1.02 pounds of CO<sub>2</sub> per pound of epoxy.

## Chapter 5: Generic Consumer Impact Analysis

A key impact of the bill that needs to be looked at is the effect of the consumer and the people at home. In this chapter we will discuss not only how EISA is going to affect what bulbs are available, but also how it is going to affect the wallets. We will explore the tradeoff between the cost of different bulbs, and when and if the energy savings is enough to bring the consumer a return on their investment.

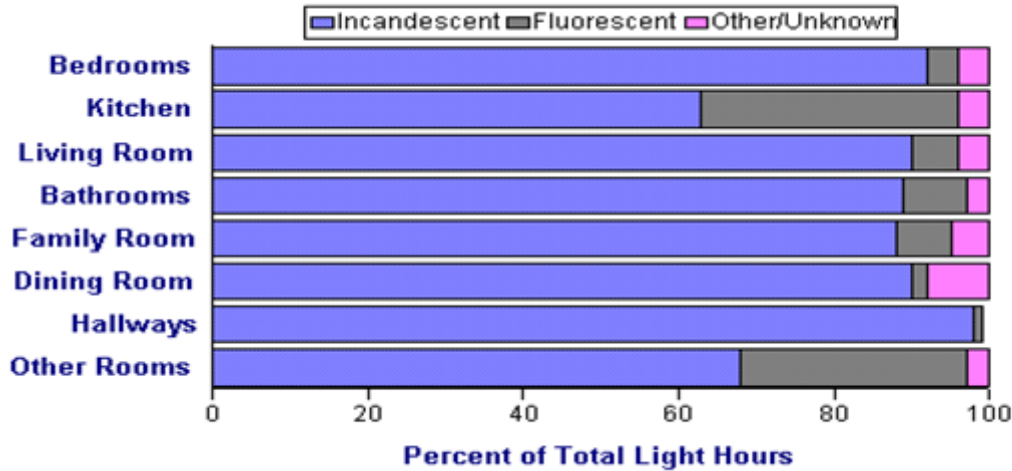
Each type of bulb is often used in separate areas of the home and in different ways in a typical household. According to the RECS Survey, 453 million lights out of 523 million (87%) regularly used domestic lamps are incandescent.<sup>51</sup> It was also estimated by the RECS that nearly 13% of lights that are used for one or more hours a day are fluorescent. Typically fluorescent bulbs are used more hours a day than the lights that are incandescent, as shown by table 5.1. The percentage of the fluorescent lights used in homes increases exponentially with respect to the average hours that light is on a day. This also shows that non-incandescent lights people use often and have on the longest in a day tend to be fluorescent bulbs rather than incandescent or halogen, since the data for those bulbs is not even shown.<sup>51</sup>

Hours Used per Day	Fluorescent as a Percent of All Lights
1 to 4	11.7
4 to 12	13.2
More than 12	20.5
Source: Energy Information Administration, Office of Energy Markets and End Use, Form EIA-457 A of the 1993 Residential Energy Consumption Survey.	

**Table 5.1:** Table is demonstrating fluorescent bulbs as a percent of total lights.<sup>51</sup>

With the trend that is noticed in the table another thing to note is that very few lights in the home are on longer than 12 hours in a day. This suggests that although the fluorescent bulbs seem to be on longer periods of the day the number of them still is low in a typical household.

Incandescent lights account for 90% of all lights in a majority of rooms in a household. As seen in figure 5.1 the number of incandescent lights in a household greatly overwhelms the number of other lights in each room. However in kitchens and “other rooms”, mostly considered as offices or work rooms for people who work from home or basements, the number of fluorescent bulbs is vast in comparison to other rooms in the house. This is most likely a result of the need of brighter light in these rooms and also correlates with the fact that the lights need to be on longer periods of times in these rooms. Other important things to note when reviewing the graph is that the percentage of fluorescent seems to be up in rooms where you would tend to see the lights on for longer periods of the day. This is a reoccurring theme from what was inferred from table 5.1. For example, in the living rooms, family rooms, and kitchen the percentage of fluorescent bulbs is higher than the percentage in rooms such as the bathroom and bedroom where the lights may not be on as long during the day. Whether on purpose or on accident, the average consumer does seem to realize that it is more effective to put more efficient bulbs in spots of the house that will require light for longer periods of times to reduce the number of times you need to purchase more bulbs. The question is when will people start using these more effective and efficient bulbs in other places, or everywhere in the house, and whether it will help them save money.<sup>51</sup>

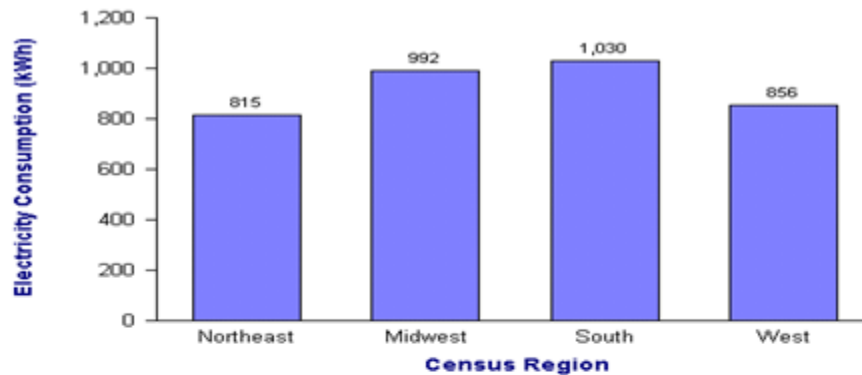


**Figure 5.1:** Graph showing the percent of various light types by room.

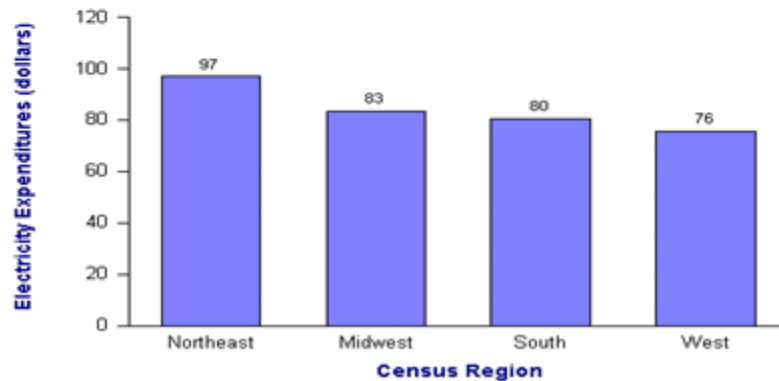
When figure 5.1 refers to other or unknown lights it is inferred that they are referring to the use of halogen or LED lights in the household. This is like an incandescent light that is more effective and efficient. A 100-watt CFL bulb typically produces 17.5 lumens per watt compared with a 100-watt halogen, which produces 18.8 lumens per watt<sup>52</sup>. The fluorescent light is much more efficient than both the other two, but the halogen light costs \$4 rather than \$22 which is the average price of a CFL bulb. This means that if people seek a bulb that is a bit more efficient than their typical incandescent bulb, but do not want to spend \$22 for a fluorescent bulb they tend to go with a halogen bulb. The use of halogen bulbs is surprisingly low considering this fact. Maybe the use of a more efficient but cheaper bulb like the halogen bulb could be a solution to satisfy more people who are against the fluorescent bulb for whatever reason.

Figure 5.2 shows two graphs that show the use of light in various regions of the United States. One graph shows the distribution in the country in kWh and the other shows the average yearly bill in dollars. For example, the average energy consumption in the Midwest was 992 kWh and as a result of that average the average energy bill was \$83 in the same region. One important thing to note is that the Northeast used on average the least amount of electricity while

they paid the most. This means that the cost of electricity is much higher in the Northeast than other areas of the United States. This is such an extreme that the Northeast on average used the least of the regions in kWh, but still paid the most for that electricity.<sup>51</sup>



Source: Energy Information Administration, Forms EIA-457A-C and E of the 1993 Residential Energy Consumption Survey.

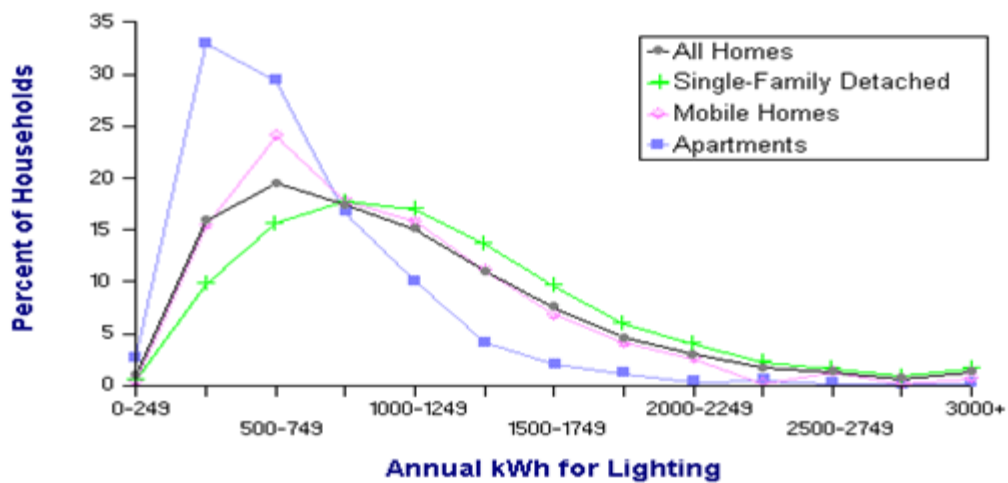


Source: Energy Information Administration, Forms EIA-457A-C, and E of the 1993 Residential Energy Consumption Survey.

**Figure 5.2:** Top graph shows kWh consumption by region where bottom graph shows electricity cost

The final thing to consider when considering a change or thinking of what may result from the changes that will occur as a result of the law passing is the type of home that you live in. As expected, you can see that different size and types of homes typically consume different

amounts of electricity. Figure 5.4 shows the percentage of homes and their annual light consumption again in kWh. A plurality of apartments (32.9 percent) consume between 250 and 499 kWh. A plurality of mobile homes (24.0 percent) consume between 500 and 749 kWh. Among single-family homes, lighting electricity use is higher, with 17.4 percent using between 750 and 999 kWh.<sup>51</sup> Apartments and mobile homes typically use less electricity than single family homes and also than the average of the group or “all homes” in the graph.



**Figure 5.3:** Graph showing electricity consumption for household type.

Now we will demonstrate how this will affect the consumer’s wallet and show the savings that everyone may or not make as a result of this bill. Households in the U. S. contain a total of 523 million lights that are on 1 or more hours a day and 282 million of these are lit for 4 or more hours a day.<sup>52</sup> A majority of those lights are incandescent, with over 85% of them being incandescent when on 4 or more hours a day. As a result of the higher efficiency in a fluorescent light over an incandescent bulb there will be a substantial amount of savings. The initial higher cost of fluorescent bulbs makes it a poor investment over a short period of time, but it can provide a return as time progresses.

The size of the home also has a large part in the amount of kWh that a home will use on a

yearly base. Table 5.2 shows the number of kWh on average in a home based on the number of rooms and also the number of family members in the household. It shows that both more rooms in the house and household members affect the amount of electricity that is used.<sup>52</sup>

		Number of Rooms						
Number of Household Members	All Households	One to Three	Four	Five	Six	Seven	Eight or More	
<i>RSE Column Factors:</i>	0.5	2.0	1.1	0.9	0.8	1.0	1.1	<i>RSE Row Factors</i>
<b>All Households</b>	940	497	690	875	1,003	1,181	1,420	2.08
One	604	443	545	629	745	910	1,028	4.76
Two	923	580	705	884	968	1,141	1,264	3.35
Three	1,023	611	789	914	1,059	1,104	1,446	4.40
Four	1,198	544	854	1,066	1,113	1,365	1,522	4.36
Five or More	1,265	597	846	1,125	1,161	1,294	1,707	5.10

**Table 5.2:** Household members and number of rooms in the house effects on electricity consumption.

To make a comparison between the two bulbs there are some assumptions that need to be made about efficiency, price, wattage, and the hours of use each day for each bulb. A 26 watt fluorescent bulb is used to compare with a 75 watt incandescent bulb. Although an 18 watt fluorescent bulb has the same light output as a 75 watt incandescent bulb the 26 watt is used to make up for possible differences in light quality and the output of the light. The 26 watt bulb is just the best to use in this comparison because it most closely resembles a typical 75 watt incandescent bulb. Another key factor is it is best to place fluorescent bulbs where lights are on for long periods of time straight, because the life a fluorescent bulb dies faster when it is turned on and off repeatedly. For the best results then replace incandescent bulbs in your home that are on more than 4 hours a day and are on for a constant time and not turned on and off too often. As



said earlier a good place for this is in kitchens, offices, and basements. Table 5.3 summarizes the assumptions made for future calculations to test savings to be made by the typical consumer. All calculations are done using the prices of the bulbs and electricity in 1993, but results now would be similar.<sup>52</sup>

	<b>Incandescent</b>	<b>Compact Fluorescent</b>
<b>Initial Cost of Bulb</b>	75 cents	22 dollars
<b>Wattage</b>	75 watts	26 watts
<b>Life of Bulb (hours)</b>	750 hours	10,000 hours
<b>Hours Used per Day</b>	6.7 hours	6.7 hours

**Table 5.3:** Summary of assumptions made for comparison.

Sources: Energy Information Administration, Office of Energy Markets and End Use; Lighting Research Center, Rensselaer Polytechnic Institute, *The Lighting Pattern Book for Homes, 1993*.

Using these assumptions on each of the two bulbs calculations are done to demonstrate when the consumer can see some savings in their budget. The calculations are done over a time period of 4.1 years as this is the period of time that a typical 26 watt fluorescent bulb will last if used 6.7 hours a day every day. In comparison an incandescent bulb tends to last about 3.5 months. Saving money will be a result of paying less for electricity when using fluorescent bulbs and saving money on not having to purchase new bulbs and replace them over the time period of 4.1 years. However it will take time for the consumer to make up ground for the initial high cost of \$22 rather than \$0.75 for incandescent. Table 5.4 shows the cost of the bulbs that would need to be purchased and the electricity if it cost 5, 10, and 15 cents per kWh. In the table the incandescent bulb cost is \$10.50 and that is because in a time period of 4.1 years an incandescent bulb would need to be changed 13 times.<sup>52</sup>

Cost of Electricity (cents per kWh)	Compact Fluorescent		Incandescent	
	Bulb Cost (dollars)	Electricity Cost (dollars)	Bulb Cost (dollars)	Electricity Cost (dollars)
5	22	12.68	10.5 <sup>a</sup>	36.56
10	22	25.35	10.5	73.13
15	22	38.03	10.5	109.69

**Table 5.4:** Table shows cost of bulbs and electricity for both cases for 3 different prices over 4.1 years.

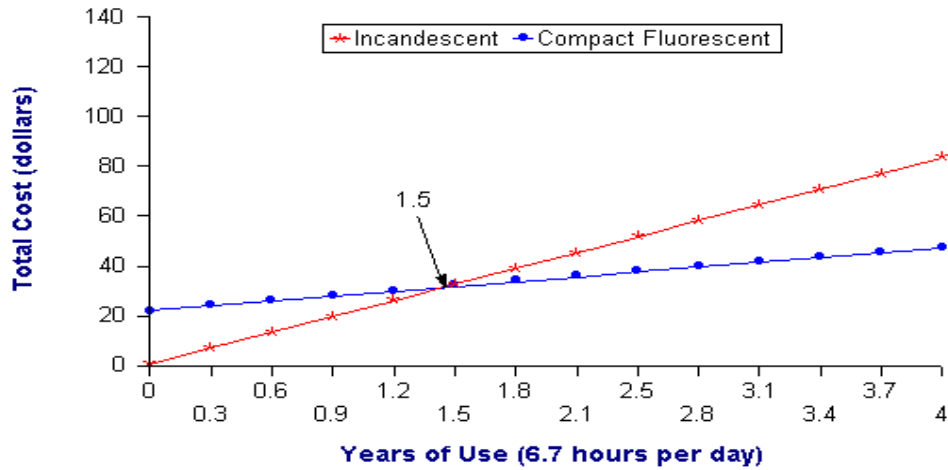
<sup>a</sup> Over a period of 4.1 years, a 75-watt incandescent bulb would have to be replaced 13 times. The initial cost of the first bulb, plus 13 replacement bulbs, times the cost of each bulb equals \$10.5 (i.e., 14 bulbs at 75 cents each).

Source: Energy Information Administration, Office of Energy Markets and End Use.

When reviewing the table you can see that at the end of the 4.1 year time period in all three cases there is considerable savings. If it cost 5 cents per kWh the consumer would save \$12.68 cents every 4.1 year time interval. For 10 cents you would save \$36.28 and for 15 cents you would save \$160.16. This is the savings that you would get every 4.1 year interval it would not continue in this trend because at the end of this time interval you would need to purchase a new fluorescent bulb at \$22 starting the whole thing over again. However, this seems to be a considerable savings even though it would take some time to really see the savings. Another thing to note is that this is just the savings as a result of one bulb, so if multiple bulbs in a home are changed to fluorescent there will be much more savings. The savings is only significant enough if the lights that are changed are bulbs that are on for over 6 hours a day. To get the best results, the consumer should take all incandescent bulbs that are on for long periods of time in their home, and change them to fluorescent bulbs to start saving money.<sup>52</sup>

Figure 5.4 shows a graph with lines for both the price of fluorescent bulbs and for incandescent bulbs. The graph shows the price for each as time passes up to 4.1 years.

**Figure 3.2. Total Cost of Compact Fluorescent Bulb Compared to Incandescent Bulb (10 cents per kWh)**



Source: Energy Information Administration, Office of Energy Markets and End Use.

**Figure 5.4:** Shows cost of each light type with price of electricity at 10 cents per kWh.

Figure 5.4 shows the trends and the prices for both the incandescent and the fluorescent bulb as time passes to the 4.1 year time interval. As expected, fluorescent bulbs are more expensive but the slope of the incandescent line is greater and eventually exceeds the fluorescent starting the savings. For this case the price for electricity is 10 cents per kWh. As the graph demonstrates the intersection point is at 1.5 years where the two are equal in price, meaning that the rest of the time interval up to 4.1 years the consumer will be saving money. As calculated earlier in this case, the total savings for each 4.1 years that the switch is made is \$36.28.<sup>52</sup>

Table 5.5 shows the number of various bulbs and sizes of the bulbs that are used in certain situations. It shows the types of bulbs that are used based on the hours that the light is typically used on a given day.

		Bulb Type								
		Incandescent				Fluorescent			Other	
Hours Used	Total	Low	Medium	High	Unknown	Short	Long	Compact	Halogen	Other/ Unknown
<b>Total</b>	4,196	431	2,811	409	14	159	173	34	24	141
Unknown	104	11	58	19	0	1	2	0	0	13
Less than One	1,106	162	746	92	3	31	26	2	4	40
1 to 1.9	994	105	710	80	3	36	27	5	4	24
2 to 3.9	1,003	58	705	113	3	30	49	11	5	29
4 to 7.9	739	52	474	81	3	36	43	12	11	27
8 to 11.9	109	9	64	17	0	8	9	1	0	1
12 or More	141	34	54	7	2	17	17	3	0	7

**Note:** These data are from the 474 households included in the Lighting Supplement. The supplement was not designed to weight the data to the population level.

**Source:** Energy Information Administration, Office of Energy Markets and End Use, Forms EIA-457A-C, E, and H of the 1993 Residential Energy Consumption Survey.

**Table 5.5:** Shows the number of various light types by hours used in an average day.

In table 5.5 there is one trend that stands out. As expected, a considerable increase in the percentage of fluorescent or even halogen bulbs as the hours used occurs. However, there is just a little bit of an increase, unlike the large increase it should be. For example, 26% of all light bulbs used over 12 hours daily are fluorescent. The 9 hours category is 12%. To the complete extreme the percentage of fluorescent bulbs used less than one hour a day is 5%. Finally an important thing to note is that the total percentage of fluorescent bulbs that are used in homes is 9%. Something that should increase is the number of halogen bulbs in areas that the bulbs are used in average amount of times like the areas 2-7.9 hours a day. The halogen bulbs have increased efficiency from the incandescent bulbs, but are cheaper in price than fluorescent bulbs.

The best solution to saving money for the average consumer is to have a large variety of lights around the house and to base what bulb to use on the average amount of hours that that bulb is on. What is recommended is that incandescent bulbs are used for lights that are on very little during an average day or are turned on and off often, as that hurts the life of both halogen and fluorescent bulbs. Halogen bulbs should be used on lamps that are used an average amount of time on a daily basis around 2 to 6 hours a day and fluorescent bulbs used for those that are used for longer periods of time then 6 hours a day. Doing this would result in an efficient system that would use less kWh and result in saving considerable money.

## **Chapter 6: Specific Consumer Impact Analysis**

One experiment that was conducted involved finding the electricity used in each of the group member's houses and assess potential savings if fluorescent bulbs were used instead of the conventional incandescent bulbs. The yearly carbon emissions due to lighting for both incandescent and fluorescent lighting configurations were also examined.

### **6.1: Lighting Consumption of House One:**

The first house evaluated was a contemporary colonial home in Southern New Hampshire. This home had approximately 3,175 square feet of living area. Each floor consisted of bulbs with wattages spanning from 40 watts to 100 watts. There were some light fixtures whose wattage was unknown to the owners of the home, which was also taken into account. The results are as follows.

The total amount of electricity used by this house hold due to lighting in one month was 270 kilowatt-hours. Using the figure of 15.2 cents per kilowatt-hour for the state of New Hampshire, the amount of money spent on lighting for each month is \$41.04.<sup>55</sup> Thus, each year, approximately \$492.48 was spending on electricity due to lighting.

The basement of the home uses approximately 2.0 kilowatt-hours per day. There are approximately 1.6 kilowatt-hours coming from light bulbs with known wattages and 0.2 kilowatt-hours coming from bulbs with unknown wattages. 0.2 kilowatt-hours were also included in this number to account for time that the bulb (or bulbs) may be inadvertently active. An example would include hallway lights that are on while the homeowner is in another part of the basement working on a project.

The first floor of the home consumes some 4.5 kilowatt hours of electricity. It uses

approximately 3.8 kilowatt-hours from known bulbs. It is estimated that 0.4 k kilowatt-hours comes from bulbs without known wattages, such as the bulbs found in the first floor lavatory and master bedroom closet. An additional 0.3 kilowatt-hours was included for time the bulbs may be left on without knowing.

The second floor of the houses utilizes 2.5 kilowatt-hours of electricity per day. Approximately 2.0 kilowatt-hours come from known bulbs and 0.2 kilowatt-hours comes from bulbs without explicitly stated wattages, such as the closet and bathroom lights. The rest (0.3 kilowatt-hours) is included to account for non-deliberate usage of the bulbs. A unique aspect about this floor is that there are only two bedrooms upstairs, and the occupants of the bedrooms are away at college for a majority of the year. Thus, only 0.3 kilowatt-hours of electricity needs to be allocated as additional usage since the primary people utilizing the second floor are out of town.

The outside of the house was assessed to be generating approximately 1.0 kilowatt-hours of electricity. The lighting itself only generated 0.2 kilowatt-hours, while 0.8 kilowatt-hours was included as possible additional time the light bulbs may be on without knowing since the occupants may venture outside of their house during the night and leave lights on outside either without knowing or just for that one occasion.

The total wattage comes to 10 kilowatt-hours in one day due to lighting. Therefore, one month uses approximately 300 kilowatt-hours of electricity, which would cost \$45.60. This number, however, is misleading because lights are more active in the winter time than in the summer. To avoid this discrepancy, a number of 270 kilowatt-hours was used, which is 10 percent less than the number in the winter months. This number served as the average for all months of the year. Therefore, as stated above, the average cost of electricity from lighting is

\$41.04 while the yearly cost is \$492.48. Using 1.3 kilowatt-hours per pound of carbon dioxide, the yearly CO<sub>2</sub> output was 4,212 lbs.<sup>56</sup>

## **6.2: Lighting Consumption of House Two:**

The lighting of another house in Massachusetts was also evaluated. This home consumed approximately 77.55 kilowatt-hours of electricity monthly. This number accounts for time that lighting is on when the owner is not aware of the fact. The results are as summarized.

The porch consumes approximately 0.015 kilowatt-hours of electricity daily. The kitchen of the home contains six 60W bulbs. The total consumption of electricity for this area is 0.45 kilowatt-hours per day. The living room consumed the most electricity in the home, with 0.6 kilowatt-hours being used for indoor lighting on a daily basis. The bedrooms in the house, including the master bedroom, consume a combined 0.32 kilowatt-hours of electricity each day. The laundry room and bathroom collectively required 0.48 kilowatt-hours of electricity to be used each day. Finally, the basement consumes the most electricity in the entire home, which amounted to 0.72 kilowatt-hours every day of the week. The daily usage of electricity from lighting totals approximately 2.585 kilowatt-hours.

The most recent price of electricity in Massachusetts is 15.53 cents per kilowatt-hour.<sup>54</sup> Using this number, the cost to light this home on a daily basis is \$0.40. For a thirty day month, the cost is \$12 and for the year it is \$144. To account for the lighting usage differential between winter and summer, 10 percent was taken off the price once again. Therefore, the total cost of electricity consumption in this home is \$10.80 per month, or \$129.60 per year. The carbon emissions for this home due to lighting for one year were determined to be 1,090.44 lbs.



### **6.3: Lighting Consumption of House Three:**

The light bulb configuration of a third house Massachusetts was also examined. This house contained all incandescent lights. The only bulbs in the house that get put to use are one 40-watt, one 60-watt, and one 75 watt. These bulbs are on for approximately 8 hours a day. The cumulative electricity consumption is then 1.4 kilowatt-hours per month, which includes the time that the lights are unknowingly on. Thus, the cost to light this home in a thirty day month is \$5.87, which includes a 10 percent deduction for the change in seasons. The cost of lighting this home in one year is \$70.44. The yearly emissions from lighting were 589.68 lbs CO<sub>2</sub>.

The final house examined was also in Massachusetts. This home primarily employed 40 watt and 60 watt light bulbs with one 100-watt bulb used in the living room. The total electricity consumed in one month by this household due to lighting is 56.97 kilowatt-hours (including ten percent factored out), which would entail an annual usage of 683.64 kilowatt-hours. The cost to light this home in a month is \$8.85, and for the year, it would be \$106.20. These numbers account for oblivious lighting usage. The annual emissions rate from lighting was 888.73 lbs CO<sub>2</sub>.

There are, of course, some discrepancies in the numbers. Sometimes lights are deliberately left on for long periods of time during special occasions, such as family get-togethers and holiday celebrations. However, there are days where the family occupying the house is away on vacation; thus, very little, if any at all, lighting is used in the house. The home owners utilize light timers, which automatically turn on and turn off house lights during the day to deter burglars from breaking in. Nevertheless, the wattages balance out to yield the figure presented earlier in this section.

#### **6.4: Lighting Consumption for House Four:**

The fourth house examined is in Massachusetts. The home currently uses just incandescent light bulbs. The wattages are 40W, 60W, and 100W. In order to achieve similar levels of luminosity, the homeowner would need to exchange the single 100W bulb for a 29W fluorescent bulb. The 60W bulbs would be exchanged with 15W fluorescent bulbs, and the 40W bulbs would be exchanged with 10W fluorescent bulbs.

Making these changes would result in bringing the yearly energy consumption from 63.3 kWh down to 16.5 kWh. This energy savings brings the annual lighting bill from \$106 to \$28. However, these new bulbs cost more money up front than incandescent ones do. Because they last several years under normal use, these bulbs would pay for themselves before they burn out.

#### **6.5: CFL Equivalents to Incandescent:**

As previously mentioned, the use of compact fluorescent light bulbs in residential spaces is a growing nationwide phenomenon. People are striving for energy savings by purchasing these bulbs that can produce equivalent lumen outputs at lower wattages, which would entail lower prices. 100-watt incandescent bulbs emit 1,750 lumens, 75-watt bulbs emit 1180 lumens, 60-watt light bulbs emit 890 lumens, and 40 watt bulbs emit 460 lumens.<sup>53</sup> For the first house examined, there are five 100-watt bulbs, two 75-watt bulbs, fourteen 60 watt bulbs, 36 50-Watt bulbs, and eight 40-watt bulbs. There are 53 40-watt bulbs that are chandelier bulbs. Therefore, they will be harder to replace. There are, however, fluorescent equivalents for the 68 bulbs that are subject to conversion. The 100-watt bulbs can be replaced by 29-watt CFL bulbs which emit the same number of lumens. The 75-watt bulbs can be replaced by 20-watt CFL bulbs which emit 1,200 lumens; 20 more than those given off by incandescent counterparts. Fourteen 15-

watt, 900 lumen producing CFL bulbs can take the place of the 60-watt incandescent bulbs already working and the 36 50-Watt incandescent bulbs that emit 385 lumens each may be replaced by a 14-watt CFL bulbs which emit 495 lumens a piece (1000 bulbs, Choose up).<sup>53 57 58</sup> The eight 40-watt incandescent bulbs may be replaced by 10-watt CFL bulbs giving off 40 more lumens each. This does not include incandescent chandelier bulbs, due to the fact that they last a considerable amount of time from seldom usage. All of this data, as well as comparisons for other types of light bulbs, can be found in Appendix A.<sup>53</sup>

### **6.6: Savings for House One:**

The cost savings for switching to fluorescent bulbs is quite significant. For the first house, the energy used per day is five kilowatt-hours per day, which would be 120 kilowatt-hours monthly. This would be reduced by 10 percent to account for summer sunshine replacing the need for light, giving a final reading of 108 kilowatt-hours per month. Taking this number and multiplying it with the cost of electricity in the state of New Hampshire, \$0.152 per kilowatt-hour, the monthly cost to light this home is \$16.42, which is less than half of the current cost.<sup>55</sup> The yearly cost for lighting would be \$197.04 and the emissions output would be 2,106 lbs CO<sub>2</sub>.

### **6.7: Savings for House Two:**

The first home in Massachusetts also exhibits substantial savings. The amount of electricity produced by the fluorescent light bulbs is 32.34 kilowatt-hours per month, all factors considered. When this number is multiplied by the current price of electricity in the state of Massachusetts, or 15.53 cents per kilowatt-hour, the cost of lighting the house on a monthly basis is \$5.02, which is less than half the cost of lighting the home with incandescent lights.<sup>54</sup> For the

year, the cost of electricity consumption due to lighting is roughly \$60.24. The annual emissions output decreases to 504.50 lbs CO<sub>2</sub>.

### **6.8: Savings for House Three:**

The third house would also benefit from CFL bulbs. If the 40-watt, 60-watt, and 75-watt bulbs were replaced with fluorescent bulbs of equivalent wattages, the cost of electricity for a thirty day month would be \$1.51 and for the year it would be \$18.12. This is less than a third of the price of using tungsten light bulbs to light up this home. The emissions output was also significantly lower, equaling 151.63 lbs CO<sub>2</sub>.

### **6.9: Savings for House Four:**

The final house would naturally yield savings as well. The bulbs in the home (40-watt, 60-watt, and 100 watt) could be substituted for 10-watt and 15-watt CFL bulbs, respectively. There would have to be a ten percent reduction in these values to account for the summer season sun. If this were to happen, the monthly electricity usage would be 14.90 kilowatt-hours. The monthly and yearly costs will also be drastically reduced as well, equaling \$2.31 and \$27.72, respectively. The emissions for this home on a yearly basis due to lighting are reduced to 232.44 lbs CO<sub>2</sub>.

### **6.10: Carbon Emissions Summary:**

We found that the average American gets electricity from sources that emit 1.3 pounds of CO<sub>2</sub> per kilowatt-hour of electricity.<sup>56</sup> Using this information, we found our annual carbon footprints based on lighting alone, and saw what kind of savings on carbon emissions we would

achieve. The results are below, showing a drastic reduction in emissions. Please note that the carbon emissions required to make these bulbs are low enough to become negligible when compared to the annual electricity consumption of the bulb.

<b>House One</b>		
Light bulb Type	kWh Per Year	Emissions Per Year
Incandescent	3,240	4,212 lbs CO <sub>2</sub>
Fluorescent	1,620	2,106 lbs CO <sub>2</sub>
<b>House Two</b>		
Light bulb Type	kWh Per Year	Emissions Per Year
Incandescent	838.8	1,090.44 lbs CO <sub>2</sub>
Fluorescent	388.08	504.50 lbs CO <sub>2</sub>
<b>House Three</b>		
Light bulb Type	kWh Per Year	Emissions Per Year
Incandescent	453.6	589.68 lbs CO <sub>2</sub>
Fluorescent	116.64	151.63 lbs CO <sub>2</sub>
<b>House Four</b>		
Light bulb Type	kWh Per Year	Emissions Per Year
Incandescent	683.64	888.73 lbs CO <sub>2</sub>
Fluorescent	178.8	232.44 lbs CO <sub>2</sub>

**Table 6.1: Carbon emissions savings**

## Chapter 7: Survey Results:

A comprehensive survey about the 2007 Energy Independence and Security Act and the controversial topic over whether incandescent or fluorescent light bulbs are the better bulb to use was conducted. A diverse group of people was surveyed, ranging from business owners to college faculty to families and friends. The survey itself with cumulative response results is included in Appendix B of this report.

### 7.1: Survey One: Dentist and CEO.

One person surveyed was Dr. H, Founder and CEO of a dental practice specializing in general and cosmetic dentistry. Dr. H proved to have intriguing views about the use of Fluorescent light bulbs over Incandescent. Dr. H's business uses Color-Correct Fluorescent Light Bulbs. Dr. H has also heard of the Energy Independence Act passed in 2007. Dr. H believes that the theory of light bulbs products being controlled by the United States Government is "countercurrent to democracy." Some of Dr. H's more copious answers are as follows:

**Interviewer:** "Would you be willing to sacrifice the freedom of purchasing incandescent light bulbs for increased energy independence?"

**Dr. H:** "I would if it would be a meaningful impact. I don't want it to have a trivial impact."

**Interviewer:** "What is your view on compact fluorescent light bulbs?"

**Dr. H:** "I'm concerned about the potential hazards in handling these bulbs and if they break. This concern is for residential spaces where small children may inadvertently break them."

Dr. H then went on to elaborate on this view. In Dr. H's dental facility, small children have little to no risk of tampering with the light fixtures in the building. Thus, fluorescent light bulbs, according to Dr. H, would be best suitable for commercial and industrial facilities.

Dr. H had heard of Halogen Light bulbs and believes they can also be used indoors if

they are environmentally safe; namely, if they do not contain hazardous chemicals like Mercury. The interview ended with a question concerning the supply and demand of light bulbs.

**Interviewer:** “As the bill states, all incandescent light bulbs of any wattage will be banned by 2014. Do you plan to stock up on these types of light bulbs?”

**Dr. H:** “For certain fixtures because of aesthetics and lighting requirements.”

### **7.2: Survey Two: Office Manager of a Dental Office.**

The wife of Dr. H was also interviewed. Mrs. H currently serves as the office manager for a dental office. Unlike Dr. H, Mrs. H had never heard of the Energy Independence and Security Act. Mrs. H does not like the notion that the government has the authority to regulate which light bulbs are not permitted to be purchased. However, Mrs. H would be amenable to sacrificing the liberty of purchasing incandescent light bulbs for increased energy dependence if there was a “safe way to do it.”

Mrs. H then went on to say that she considered fluorescent bulbs to be dangerous because “if you drop them, they explode and spill Mercury.” This coincides with past opinions on the perils of Mercury in indoor lighting. Surprisingly, Mrs. H has heard of Halogen and LED lighting indoors, but has no idea what they are or how they will be used. She concluded by giving the affirmative to the same question asked to the previous interviewee: Mrs. H will be stocking up on incandescent light bulbs before 2014.

### **7.3: Survey Three: WPI Professor:**

In an effort to diversity the interviewees, a well-known professor at Worcester Polytechnic Institute was interviewed. The professor had heard of the Energy Independence and

Security Act. The answers the professor divulged were as follows:

**Interviewer:** “What do you think of the idea of the government mandating the types of light bulbs consumers can purchase?”

**Professor:** “It’s philosophically disappointing, but effective in practical terms.”

**Interviewer:** “Would you be willing to sacrifice the freedom of purchasing incandescent light bulbs for increased energy independence?”

**Professor:** “With a qualifier, then yes. If I can get something that is equivalent in lumen output, then yes.”

The professor stated that he primarily uses incandescent light bulbs over fluorescent. He believes that fluorescent light bulbs simply “do not produce enough light.” The professor has also heard of using Halogen or LED light bulbs indoors, however, he would only use them for certain applications. When the professor was asked if he would stock up on incandescent light bulbs, he said “my wife wants me too.”

At the end of the interview, the professor summarized his beliefs on fluorescent light bulbs.

“I am totally in favor of energy conservation; it does not take a lot to save energy in power plants. The problem is I need a lot of lighting to grade papers so I need an equivalent substitute for incandescent lights. If there is a light out there that is equivalent in lumen strength to that of incandescent light bulbs, I will buy it. The amount of money the bulb costs is not the determining factor.”

#### **7.4: Survey Four: Second WPI Professor:**

Another professor from the same school was interviewed. He had heard of the Energy



Independence and Security Act and gave an intriguing perspective on whether the government should mandate what types of light bulbs consumers can purchase:

“As an engineer, it is more a question of performance rather than type. It is a question of the industry devising solutions for better performance.”

The professor would be willing to sacrifice the ability to choose which light bulbs he can buy for energy dependence. He also uses incandescent bulbs in favor of fluorescent bulbs.

When asked about his opinion of fluorescent light bulbs, he did not have an aversion to the light bulb itself, but rather the disposal “being a pain” when they burn out.

The professor is also an advocate of halogen and LED light bulbs being used for indoor lighting. When asked whether he planned on stocking up on incandescent light bulbs before production hinders in 2014, he gave the following response:

“I don’t see myself doing that, at least for overhead or reading bulbs. I would stock up on specialty ones since I don’t replace many of them in my lifetime.”

He concluded the interview with an example of his refrigerator. The professor explained that he would probably replace his refrigerator bulb only three or four times throughout his entire life, therefore, he does an importance in acquiring specialty bulbs for a purpose such as refrigeration.

### **7.5: Survey Five: Father of the CEO**

The father of Dr. H, Sr. H also took part in the interview. Sr. H was aware of the 2007 Energy Independence and Security Act. When asked about the idea of the government being able to mandate which types of light bulbs can be purchased, the following answer was given

“In a sense that it will eventually conserve electricity, it is good. I know people may not

like this, but it is a matter of energy conservation.”

Sr. H currently uses both fluorescent and incandescent light bulbs and hopes to one day switch to fluorescent and LED bulbs. Sr. H does, however, favor LED bulbs over fluorescent bulbs:

“LED bulbs are far superior. With less voltage, more light is produced. Fluorescent bulbs do not give enough light. LED’s are expensive now, however, in the future; they will go down in price.” Sr. H does not plan on stocking up on incandescent light bulbs despite the 2014 ban.

#### **7.6: Cumulative Survey Results:**

A total of 28 people, including the individual responses given above, were interviewed. The cumulative survey results for every question were as follows.

For the first question, 57 percent of the respondents have heard of the Energy Independence and Security Act while the other 43 percent have not. Some people had not heard of the law itself, but through hearing various fragments of information regarding light bulbs, knew that incandescent light bulbs were being phased out. The second question yielded responses of 61 percent assenting to government regulation over the purchase of light bulbs whereas the remaining 32 percent believed it would give the government too much power and authority over consumer purchases. Some people believe the government can mandate light bulb purchases as long as it does not entail higher prices for the consumer. The other 18 percent were neutral.

As stated previously, the third question asked whether people would be willing to sacrifice purchasing freedom for bolstered energy independence. A whopping 79 percent agree

with the idea that the public should be willing to give up their light bulb liberties for energy independence. Some people hope the mandate will have a meaningful impact. 18 percent were not in favor of sacrificing their purchasing power. The other 3 percent were neutral.

It appears that most people primarily use incandescent light bulbs in their homes. 79 percent primarily use traditional tungsten bulbs while only 7 percent use fluorescent bulbs. The other 14 percent have an even number of both. Some people use fluorescent bulbs on one floor of the house, while the other floors are still lit up by incandescent bulbs.

There are many different views on fluorescent bulbs. Naturally, the most common worry was the mercury inside the bulb. As noted above, the disposing of CFL bulbs can be precarious because of the innate risks of mercury if a bulb is broken and mercury disperses over a surface. One person, however, believed that fluorescent bulbs can only be dimmed if their lifetime is significantly reduced.

The results for the sixth question are more complex. Out of the 28 people surveyed, 57 percent had heard of indoor LED lighting while 61 percent know about halogen lights used indoors. 43 percent have not heard of LED bulbs being used indoors while 39 percent have not heard of indoor halogen lighting. The seventh question explored Halogen and LED bulbs in more detail. 79 percent would use either type. 11 percent would not use any of them. 10 percent were neutral on the issue. One person likes the prospect of LED bulbs, but not Halogen because they are wasteful. One other individual believes they contain the risk of fire. Some people do use LED bulbs and are in favor of them. Most people cited money as a primary consideration on what type of bulb they would purchase.

The final question asked respondents if they would stock up on incandescent light bulbs before the ban in 2014. The results were quite surprising. Only 18 percent agreed they would

stock up on tungsten bulbs while 82 percent believed that it does not make sense to buy large quantities of these bulbs. It appears that most people will be willing to adjust to the new mandate.

## Chapter 8: Conclusions

The Energy Independence and Security Act of 2007 will have lasting and sweeping effects on American lighting and energy. On 1 January 2012, the light bulb restrictions began with effectively banning 100W incandescent bulbs. By 2014, all incandescent bulbs over 40W will effectively be off the market. This change will affect nearly every household in America, forcing consumers to change the way they light their houses. The eventual absence of the typical bulbs consumers have bought for decades will force consumers to shop around for their new favorite bulbs.

As demonstrated, a change as sweeping as this was always bound to cause an uproar among some of the more freedom-minded Americans. The coming changes had been met with stiff opposition from talk radio, some cable news programs, and many freedom-minded groups around the country. Because of the outrage in some quarters, lawmakers in several states and even in the U.S. House of Representatives have attempted to thwart the mandates. The issue became political enough where the U.S. House was able to prevent the enforcement of the law until late 2012, although this measure will not affect the way light bulb manufacturers conduct their operations from what they had planned for.

The ultimate question that guides consumers about buying different types of bulbs is “which one will save me the most money?” To be sure, many consumers take into account the appearance of the bulbs and how the lighting affects their home’s appearance. However, many consumers just care about their wallets, especially in a tough economy.

We have demonstrated that the histories of CFL, halogen, and LED bulbs are relatively short, which suggests further technological improvement is likely to lower costs and improve lighting quality. Because of this, we expect consumers to meet the new bulbs with little

resistance. As we have shown in chapter three, previous concerns by consumers about the curly appearance of CFL lamps have already been met by some manufacturers, who have encased the bulbs in a more traditional bulb shape to appeal to skeptical customers more effectively. We expect more of this refinement to continue as the different technologies compete with one another on the market.

We have also discussed the material composition of incandescent, fluorescent, halogen, and LED bulbs, and their impact on the environment. We have also examined the manufacturing process for each of these bulbs. This was essential to gaining an understanding of what makes these popular types of bulbs different from one another.

The manufacturing processes are similar for incandescent, fluorescent, and halogen bulbs. They also have similar material composition, up to a few small differences, namely, the type of glass used as a casing, and the type of gas inside the tube. Despite their use of mercury as an essential ingredient, incandescent bulbs do not appear to pose any significant health risk. The manufacturing processes for these three types of bulbs emit so little CO<sub>2</sub>, that these emissions pale in comparison to the emissions of their electricity use over their lifespan.

With respect to the generic consumer impact analysis, a few conclusions can be made. One conclusion that is evident is that, regardless of the high initial cost of a fluorescent bulb compared to an incandescent bulb, savings can be made. Chapter 5 showed that on intervals of 4.1 years considerable money on the lighting part of the household electricity bill would be made simply with the change of a single bulb in the house. If multiple bulbs throughout the house were changed to fluorescent bulbs the savings would be greater.

Another aspect to consider is the average time the bulb is on before change s made along with how it is used. Lights that are turned on and off constantly like in a hallway, and are not on

for a long period of time should not be changed as this hurts the life of a fluorescent bulb. These lights in a home should stay as incandescent bulbs because they are the cheapest to replace. Halogen bulbs can also be helpful in bulbs that are on for an average length of time, but are also not as expensive as a fluorescent light. The most efficient thing to do to your home to save the maximum amount of money in a household would be to use incandescent bulbs in areas that light is not used in long periods of times, halogen bulbs in areas where the light is used an average amount of times, and fluorescent bulbs for those lights that are on a large portion of the day.

After conducting a thorough analysis of the housing data collected, it appears that the majority of homeowners utilize traditional tungsten bulbs, albeit the implementation of fluorescent bulbs would entail significant cost and emissions savings. The cost and emissions savings for fluorescent light bulb conversion range between 50 and 80 percent for each category. The cost of fluorescent bulbs is also far cheaper than that of common incandescent light fixtures.

The survey results proved rather surprising. When respondents were asked about their home lighting configurations, the primary answer was “all incandescent.” As stated above, only 14 percent of the interviewees had a “half-and-half” arrangement. The reason is primarily related to the hazards of Mercury in the CFL bulbs. 79 percent of the people responding would be willing to try Halogen and LED bulbs in their homes.

Considering this survey data, it would make sense that people would stock up on incandescent bulbs as soon as they are phased out. This proved not to be the case, with 82 percent of the respondents dissenting to stocking up on tungsten bulbs. It appears that the general public, though 57 percent of the people interviewed had heard of the Energy Independence and Security Act, are willing to make a gradual transition into a new era of lighting.

## Works Cited

- <sup>1</sup> "GlobalWarming.House.Gov | Legislation." *The Select Committee for Energy Independence and Global Warming*. Web. 17 Feb. 2012. <<http://globalwarming.house.gov/legislation?id=0002>>.
- <sup>2</sup> "The Little-Known 2007 Energy Law That May Have a Big Effect on Oil Consumption | 80beats | Discover Magazine." *Discover Blogs | Discover Magazine*. Web. 17 Feb. 2012. <<http://blogs.discovermagazine.com/80beats/2011/03/25/the-little-known-2007-energy-law-that-may-have-a-big-effect-on-oil-consumption/>>.
- <sup>3</sup> "Congressman Nick Rahall : Mining & Energy." *Congressman Nick Rahall : Home*. Web. 17 Feb. 2012. <<http://www.rahall.house.gov/index.cfm?sectionid=34>>.
- <sup>4</sup> "Congress.org - Key Votes." *Congress.org - Get Informed, Get Involved*. Web. 17 Feb. 2012. <<http://www.congress.org/congressorg/aol04/issues/votes/?votenum=1177>>.
- <sup>5</sup> "President Bush Signs H.R. 6, the Energy Independence and Security Act of 2007." *Welcome to the White House*. Web. 17 Feb. 2012. <<http://georgewbush-whitehouse.archives.gov/news/releases/2007/12/20071219-6.html>>.
- <sup>6</sup><http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA475228&Location=U2&doc=GetTRDoc.pdf>
- <sup>7</sup>[http://www.nytimes.com/2011/08/11/garden/almost-time-to-change-the-light-bulb.html?pagewanted=1&\\_r=2](http://www.nytimes.com/2011/08/11/garden/almost-time-to-change-the-light-bulb.html?pagewanted=1&_r=2)
- <sup>8</sup> "INLAND: It's Lights out for 100-watt Bulbs | Breaking News | PE.com - Press-Enterprise." *Breaking News | PE.com - Press-Enterprise*. Web. 17 Feb. 2012. <<http://www.pe.com/local-news/local-news-headlines/20110926-inland-its-lights-out-for-100-watt-bulbs.ece>>.
- <sup>9</sup> "Bill Summary & Status - 112th Congress (2011 - 2012) - H.R.849." *THOMAS (Library of Congress)*. Web. 17 Feb. 2012. <<http://thomas.loc.gov/cgi-bin/bdquery/z?d112:h.r.849>>.
- <sup>10</sup>[http://www.nytimes.com/2011/08/11/garden/almost-time-to-change-the-light-bulb.html?pagewanted=1&\\_r=1](http://www.nytimes.com/2011/08/11/garden/almost-time-to-change-the-light-bulb.html?pagewanted=1&_r=1)
- <sup>11</sup> "The History of the Light Bulb." *INVSEE: Come, Explore The Nano-world!!* Web. 17 Feb. 2012. <<http://invsee.asu.edu/modules/lightbulb/meathist.htm>>.
- <sup>12</sup> "The History of the Light Bulb – An Electric Dawn." *TheHistoryOf.net*. Web. 17 Feb. 2012. <<http://www.thehistoryof.net/the-history-of-the-light-bulb.html>>.
- <sup>13</sup> "History of the Incandescent Light." *The Edison Tech Center*. Web. 17 Feb. 2012. <<http://edisontechcenter.org/incandescent.html>>.



- <sup>14</sup> "Alexander Lodygin." *Txchnologist*. Web. 17 Feb. 2012.  
<<http://www.txchnologist.com/2011/in-the-beginning-a-gallery-of-pre-edison-light-bulbs/alexander-lodygin>>.
- <sup>15</sup> Bellis, Mary. "The History of Fluorescent Lights and Fluorescent Lamps." *Inventors*. Web. 17 Feb. 2012. <[http://inventors.about.com/library/inventors/bl\\_fluorescent.htm](http://inventors.about.com/library/inventors/bl_fluorescent.htm)>.
- <sup>16</sup> "Fluorescent Lamp History." *The Edison Tech Center*. Web. 17 Feb. 2012.  
<<http://www.edisontechcenter.org/fourescentlampdev.html>>.
- <sup>17</sup> "How Halogen Lamp Is Made - Material, Manufacture, Making, History, Used, Processing, Parts, Components, Dimensions, Procedure, Industry, Machine, History, Raw Materials, Design." *How Products Are Made*. Web. 17 Feb. 2012. <<http://www.madehow.com/Volume-6/Halogen-Lamp.html>>.
- <sup>18</sup> "Halogen Lamps - How They Work & History." *The Edison Tech Center*. Web. 17 Feb. 2012.  
<<http://edisontechcenter.org/halogen.html>>.
- <sup>19</sup> Margolin, Jed. "Road to the Transistor." *Jed Margolin*. Web. 17 Feb. 2012.  
<<http://www.jmargolin.com/history/trans.htm>>.
- <sup>20</sup> <http://www.nature.com/nphoton/journal/v1/n4/full/nphoton.2007.34.html>
- <sup>21</sup> "Phys. Rev. 99, 1892 (1955): Radiative Transitions in Semiconductors." *Physical Review Online Archive (PROLA)*. Web. 17 Feb. 2012.  
<[http://prola.aps.org/abstract/PR/v99/i6/p1892\\_1](http://prola.aps.org/abstract/PR/v99/i6/p1892_1)>.
- <sup>22</sup> "The Quartz Watch." Web. 17 Feb. 2012.  
<<http://invention.smithsonian.org/centerpieces/quartz/inventors/biard.html>>.
- <sup>23</sup> "Winners' Circle: Nick Holonyak, Jr." *MIT - Massachusetts Institute of Technology*. Web. 17 Feb. 2012. <<http://web.mit.edu/invent/a-winners/a-holonyak.html>>.
- <sup>24</sup> "Cookies Required." *Applied Physics Letters*. Web. 17 Feb. 2012.  
<[http://apl.aip.org/resource/1/applab/v28/i9/p499\\_s1](http://apl.aip.org/resource/1/applab/v28/i9/p499_s1)>.
- <sup>25</sup> "UCSB Press Release: "2006 MILLENNIUM TECHNOLOGY PRIZE AWARDED TO UCSB'S SHUJI NAKAMURA World's Biggest Technology Prize Includes \$1.3-Million Cash Award"" *Institutional Advancement*. Web. 17 Feb. 2012.  
<<http://www.ia.ucsb.edu/pa/display.aspx?pkey=1475>>.
- <sup>26</sup> "Crystal Coat Warms up LED Light - Tech - 01 February 2008 - New Scientist." *Science News and Science Jobs from New Scientist - New Scientist*. Web. 17 Feb. 2012.  
<[http://www.newscientist.com/article/dn13266-crystal-coat-warms-up-led-light.html?feedId=online-news\\_rss20](http://www.newscientist.com/article/dn13266-crystal-coat-warms-up-led-light.html?feedId=online-news_rss20)>.

- <sup>27</sup> "NEMA - CFL Market Share Rises During Second Quarter." *NEMA - National Electrical Manufacturers Association*. Web. 17 Feb. 2012. <<http://www.nema.org/media/pr/20090813a.cfm>>.
- <sup>28</sup> "Spending Bill Blocks Light Bulb Standards - Darren Samuelsohn - POLITICO.com." *Politics, Political News - POLITICO.com*. Web. 01 Feb. 2012. <<http://www.politico.com/news/stories/1211/70534.html>>.
- <sup>29</sup> "Industry: Light Bulb War a Dim Idea - Robin Bravender - POLITICO.com." *Politics, Political News - POLITICO.com*. Web. 01 Feb. 2012. <<http://www.politico.com/news/stories/1211/70621.html>>.
- <sup>30</sup> Restuccia, Andrew. "Despite GOP Opposition, Light Bulb Standards Will Phase in on Jan. 1." *The Hill*. News Communications, Inc., 29 Dec. 2011. Web. 30 Dec. 2011.
- <sup>31</sup> "Lawmaker Opposing Light Bulb Ban in Virginia - CBS News." *Breaking News Headlines: Business, Entertainment & World News - CBS News*. Web. 12 Feb. 2012. <[http://www.cbsnews.com/8301-505245\\_162-57363891/lawmaker-opposing-light-bulb-ban-in-virginia/](http://www.cbsnews.com/8301-505245_162-57363891/lawmaker-opposing-light-bulb-ban-in-virginia/)>.
- <sup>32</sup> "New Efficiency Standards." *LightingFacts.com*. Web. 12 Feb. 2012. <<http://www.lightingfacts.com/default.aspx?efficiency>>.
- <sup>33</sup> Moorefield, Laura. "Next Generation Lighting: Policy Changes & Program Implications." *Midwest Energy Efficiency Alliance*. 13 Jan. 2011. Web. 12 Feb. 2012.
- <sup>34</sup> "Cleaning Up a Broken Compact Fluorescent Light Bulb (CFL) | Compact Fluorescent Light Bulbs (CFLs) | US EPA." *US Environmental Protection Agency*. Web. 12 Feb. 2012. <<http://epa.gov/cfl/cflcleanup.html>>.
- <sup>35</sup> "How Products Are Made." *How Light Bulb Is Made*. Web. 23 Feb. 2012. <<http://www.madehow.com/Volume-1/Light-Bulb.html>>.
- <sup>36</sup> "DUEMT . NET Everything You Wanted To Know About Dumet Wire." *Light Bulb*. Web. 23 Feb. 2012. <[http://www.dumet.net/light\\_bulb.html](http://www.dumet.net/light_bulb.html)>.
- <sup>37</sup> "-Fluorescent Lamp Making Plant." *Proyecto Preliminares Para Las Plantas Industriales*. Web. 24 Feb. 2012. <<http://turnkey.taiwantrade.com.tw/en/Content.aspx?ID=66>>.
- <sup>38</sup> "Health Effects." *EPA*. Environmental Protection Agency. Web. 23 Feb. 2012. <<http://www.epa.gov/hg/effects.htm>>.
- <sup>39</sup> "Mercury, Elemental (CASRN 7439-97-6) | IRIS | US EPA." *EPA*. Environmental Protection Agency. Web. 23 Feb. 2012. <<http://www.epa.gov/iris/subst/0370.htm>>.
- <sup>40</sup> "Compact Fluorescent Light Bulbs." *Illinois Department of Public Health Home Page*. Web. 23 Feb. 2012. <[http://www.idph.state.il.us/envhealth/factsheets/fluorescent\\_light\\_bulb.htm](http://www.idph.state.il.us/envhealth/factsheets/fluorescent_light_bulb.htm)>.

- <sup>41</sup> "How Products Are Made." *How Halogen Lamp Is Made*. Web. 23 Feb. 2012. <<http://www.madehow.com/Volume-6/Halogen-Lamp.html>>.
- <sup>42</sup> "How LED Light Bulbs Are Made." *LED Tube Lights*. Web. 23 Feb. 2012. <<http://www.ledtubelights.org/how-led-light-bulbs-are-made>>.
- <sup>43</sup> "How Light Bulbs Work." *HowStuffWorks*. Web. 24 Feb. 2012. <<http://www.howstuffworks.com/light-bulb.htm>>.
- <sup>44</sup> *HowStuffWorks*. Web. 24 Feb. 2012. <<http://home.howstuffworks.com/fluorescent-lamp2.htm>>.
- <sup>45</sup> "How Does a Halogen Light Bulb Work?" *HowStuffWorks*. Web. 24 Feb. 2012. <<http://www.howstuffworks.com/question151.htm>>.
- <sup>46</sup> "Halogen Lamp." *Enotes.com*. Enotes.com. Web. 24 Feb. 2012. <<http://www.enotes.com/halogen-lamp-reference/halogen-lamp>>.
- <sup>47</sup> *HowStuffWorks*. Web. 24 Feb. 2012. <<http://www.howstuffworks.com/environmental/green-tech/sustainable/led-light-bulb1.htm>>.
- <sup>48</sup> "How Products Are Made." *How Light-emitting Diode (led) Is Made*. Web. 24 Feb. 2012. <<http://www.madehow.com/Volume-1/Light-Emitting-Diode-LED.html>>.
- <sup>49</sup> *HowStuffWorks*. Web. 24 Feb. 2012. <<http://www.howstuffworks.com/environmental/green-tech/sustainable/led-light-bulb1.htm>>.
- <sup>50</sup> <http://www.madehow.com/Volume-1/Light-Emitting-Diode-LED.html>
- <sup>51</sup> Berry, Chip. "Residential Lighting Profile." *U.S. Energy Information Administration (EIA)*. Web. 09 Feb. 2012. <<http://www.eia.gov/emeu/lighting/chap2.html>>.
- <sup>52</sup> Berry, Chip. "Potential for Savings." *U.S. Energy Information Administration (EIA)*. Web. 09 Feb. 2012. <<http://www.eia.gov/emeu/lighting/chap3.html>>.
- <sup>53</sup> EFI. "Lumen Table." *EFI.org*. 29 Jan, 2012 <<http://www.efi.org/factoids/lumens.html>>
- <sup>54</sup> Institute for Energy Research. "Massachusetts." *Institute for Energy Research*. 5<sup>th</sup> December, 2011. <<http://instituteforenergyresearch.org/states/massachusetts>>
- <sup>55</sup> Institute for Energy Research. "New Hampshire." *Institute for Energy Research*. 5<sup>th</sup> December, 2011. <<http://www.instituteforenergyresearch.org/states/new-hampshire/>>

<sup>56</sup> "CO2 Emissions Report." *U.S. Energy Information Administration (EIA)*. Web. 20 Feb. 2012.  
<[http://www.eia.gov/cneaf/electricity/page/co2\\_report/co2report.html](http://www.eia.gov/cneaf/electricity/page/co2_report/co2report.html)>.

<sup>57</sup> 1000 Bulbs. "Phillips 16755-1-50 Watt – R20LN." 1000bulbs.com. 25 January, 2012  
<<http://www.1000bulbs.com/product/4764/FL-167551.html>>

<sup>58</sup> Choose Up "14 Watt Flood CFL." Chooseup.com. 25 January, 2012  
<<https://www.chooseup.com/products/cfls/14-watt-flood-cfls-r20>>

## Appendix A: Complete home lighting analysis

House One:						
Light Quantity	Location	Hours Of Use Per Day	Wattage of Incandescent	Wattage of CFL	kWh Per Day (current)	kWh Per Day (potential)
8	Basement	2	60	15	0.96	0.24
16	Basement	0.5	50	14	0.4	0.112
2	Basement	0.5	60	15	0.06	0.015
1	Basement	0.25	75	20	0.02	0.005
4	Basement	0.5	50	14	0.1	0.028
2	Basement	0.05	50	14	0.005	0.0014
3	First floor	3	60	Specialty	0.54	0.54
3	First floor	0.15	50	Halogen	0.023	0.023
18	First floor	0.1	40	Chandelier	0.072	0.072
8	First floor	4	50	14	1.6	0.448
3	First floor	5	100	29	1.5	0.435
2	First floor	0.1	40	10	0.008	0.002
2	First floor	0.3	60	15	0.036	0.009
2	Second Floor	2	100	29	0.4	0.116
44	Second Floor	0.25	50	14	0.05	0.014
2	Second Floor	6	60	15	0.72	0.18
1	Second Floor	5	75	20	0.375	0.1
21	Second Floor	0.25	40	Chandelier	0.21	0.21
1	Second Floor	6	40	10	0.24	0.06
4	Second Floor	0.1	40	10	0.016	0.004
14	Porch	0.25	40	Specialty	0.14	0.14
2	Porch	0.5	50	14	0.05	0.014
				Total:	7.525	2.7684
					Adjusted total: 10 kWh	Adjusted Total: 5 kWh
					Real Total: 9 kWh	Real Total: 4.5 kWh

					<b>Annual Cost: \$492.48</b>	<b>Annual Cost: \$197.04</b>
--	--	--	--	--	----------------------------------	----------------------------------

House Two:						
Light Quantity	Location	Hours Of Use Per Day	Wattage of Incandescent	Wattage of CFL	kWh Per Day (current)	kWh Per Day (potential)
1	Porch	1	15	3	0.015	0.015
3	Kitchen	2	60	15	0.36	0.09
1	Kitchen	0.17	60	15	0.01	0.0025
2	Kitchen	1	40	10	0.08	0.02
1	Living Room	3	60	15	0.18	0.045
1	Living Room	7	60	15	0.42	0.105
2	Master Bedroom	0.5	60	15	0.06	0.015
1	Bedroom 1	0.33	60	15	0.02	0.005
2	Bedroom 2	2	60	15	0.24	0.06
1	Bathroom	2	60	15	0.12	0.03
6	Basement	6	20	Specialty Bulb	0.72	0.72
2	Laundry Room	3	60	15	0.36	0.09
				Adjusted Total:	2.585	1.1975
				Real Total:	2.33	1.078
					<b>Annual Cost: \$129.60</b>	<b>Annual Cost: \$60.24</b>

House Three:						
Light Quantity	Location	Hours Of Use Per Day	Wattage of Incandescent	Wattage of CFL	kWh Per Day (current)	kWh Per Day (potential)
1	First Floor	8	40	10	0.32	0.08
1	First Floor	8	60	15	0.48	0.12
1	First Floor	8	75	20	0.6	0.16
				Adjusted Total:	1.4	0.36
				Real Total:	1.26	0.324
					<b>Annual Cost: \$70.44</b>	<b>Annual Cost: \$18.12</b>

House Four:						
Light Quantity	Location	Hours Of Use Per Day	Wattage of Incandescent	Wattage of CFL	kWh Per Month (current)	kWh Per Month (potential)
1	Living Room	6	100	29	18	5.22
4	Living Room	4	40	10	19.2	4.8
2	Dining Room	1	60	15	3.6	0.9
1	Kitchen	3	40	10	6	1.5
1	Kitchen	2	40	10	2.4	0.6
4	Living Room	0.5	40	10	2.4	0.6
2	Downstairs Bathroom	0.5	60	15	1.8	0.45
1	Evaluator's Bedroom	0.5	60	15	0.9	0.225
4	Upstairs Bathroom	1	60	15	7.2	1.8
1	Parents' Bedroom	0.5	60	15	0.9	0.225
1	Brother's Bedroom	0.5	60	15	0.9	0.225
				Adjusted Total:	63.3	16.545
				Real Total:	56.97	14.9
					<b>Annual Cost: \$106.20</b>	<b>Annual Cost: \$27.72</b>



## Appendix B: Survey Question Responses:

1. Have you heard of the Energy Independence and Security Act of 2007?

Yes – 16

No – 12

Comments:

One person hadn't heard the title of the law, but was aware that the bulbs are being phased out.

2. What do you think of the idea of the government mandating the types of light bulbs consumers can purchase?

Agree -17

Disagree – 9

Neutral -2

Comments:

Two people said that these sorts of mandates are okay if they will not cost the people more money than if there were no mandate.

Two other people said that people who are opposing the law are just being “difficult.”

3. Would you be willing to sacrifice the freedom of purchasing incandescent light bulbs for increased energy independence?

Yes – 22

No – 5

Neutral 1

Comments:

One person didn't mind losing that freedom personally, but disagrees philosophically with the mandate.

One person would sacrifice this freedom if it would have a meaningful impact.

4. Do you primarily use incandescent light bulbs in favor of fluorescent ones?

Yes – 22

No – 2

Half and half – 4

Comments:

Two people (who live in the same household) use CFL bulbs in their basement.

5. What do you think about fluorescent light bulbs?

Comments:

One person was concerned about the presence of mercury in CFL bulbs.

One person thought it is slightly annoying that they take a second to light up, but that is one of the people who actually own CFLs.

Other than the one person concerned about mercury, the others thought the bulbs were okay. No one really loved them.

One person says that they are good, but they can't be dimmed unless the lifetime is significantly reduced.

6. Have you ever heard of using LEDs or halogen bulbs for domestic lighting?

LEDs:

Yes – 16

No – 12

Halogen:

Yes – 17

No – 11

7. If so, would you consider using them?

Yes – 22

No – 3

Neutral - 3

Comments:

One person had heard that halogen bulbs have a risk of fire.

One person actually owns an LED light bulb in her home and really likes it.

All respondents cited money as a primary consideration they would use.

8. As the bill states, all incandescent bulbs 40W and above will effectively be banned by

2014. Do you plan to stock up on these bulbs?

Yes – 5

No – 23

Comments:

Most people said that it makes more sense to get used to the new bulbs rather than stock up on them.