Strategies to Reduce Energy Consumption and Waste Production Through Moderate Lifestyle Modifications

An Interactive Qualifying Project Report

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by

Nicholas DeFilippo

Haley Hayden

Alexander Kopchik

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Professor N. A. Deskins, Major Advisor

1. Abstract

Energy is a topic of debate and concern among the citizens of the world. The earth's main energy sources are becoming more and more scarce and the waste produced by consuming the sources of energy is polluting ecosystems across the globe. Reducing energy usage and the subsequent production of waste is crucial to prolonging the life of the fragile ecosystems as well as reducing our dependence on nonrenewable resources. Using less energy has obstacles, such as monetary costs or a personal effort that many people may not be willing or able to make. In this report, we seek to specifically outline where the individual can make a significant difference in energy consumption through modest behavioral changes. Through research, we are able to split the energy usage of individuals in the United States into three sectors where the most energy is consumed: personal transportation, food consumption, and climate control. We combine a wide range of data collected by previous studies to recommend modest behavioral changes that the average United States citizen can make to reduce the amount of energy he or she consumes.

2. Acknowledgements

First and foremost, we would like to thank Professor N. Aaron Deskins for his dedication and guidance throughout the project. He not only provided direction on the project, but also taught us many skills that can continue to be invaluable as we move into our professional careers.

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Next, we would like to acknowledge the contributions of the WPI library staff as they helped us get started with our research, organize our citations, reveal diverse resources, and showed us how to access additional off-campus resources.

Finally we would like to Professor James Doyle for giving us some of our most valuable sources for energy saving strategies.

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6. Introduction

Global warming, carbon footprints, and green energy are all popular topics that are trending in modern culture. These topics spawn a growing concern for the planet's health, and consequently both energy and waste management. The concern for the health of our planet appears to be on the forefront of the societal mind, as the planet's health directly impacts the health and sustainability of human life. The rising concern for sustainability in the populous is evident from the increased publicity "going green" has received encouraging consumers to use reusable shopping bags and buy goods made from recycled products. As this concern grows, people should begin to ask themselves: how can I, as a human being, preserve the planet's health and make the world a better place through changes to my daily life to minimize both energy consumption and waste production, in the form of carbon dioxide?

Currently the primary resources that energy is produced from are fossil fuels, specifically oil, coal, and natural gas. These sources of energy result in two major problems. The first problem is that these energy sources are limited non-renewable resources meaning that eventually, the supply will be gone and new sources of energy will need to be found. The second problem is that even if there were unlimited quantities, these energy sources result in large amounts of waste production in the form of greenhouse gases, specifically carbon dioxide, ozone, and other pollutants. These gases result in negative global occurrences, such as increased atmospheric temperature, acid rain, and smog (Goldemberg, 2012). Knowledge of what energy is produced from allows the best possible decision to be made for saving energy and reducing waste based on the source of energy consumed.

Despite the fact that individuals typically cannot influence how energy is produced, it is still an important topic to look at. The source of production for energy determines the relative type and amount of waste produced. Thus, if an individual wants to minimize waste production, it is important to know the resource that is consumed to produce the waste. By monitoring individual energy consumption and waste production any individual can positively benefit the planet's health through four overarching benefits. First, reducing energy consumption will often reduce the amount of money the individual spends on energy whether it is on gas for the car or electricity for the house. Secondly, if energy consumption decreases, then less fossil fuels are required to produce the necessary energy which allows stores of fossil fuels to last longer. The third benefit is that reducing energy consumption and waste production will reduce the production of harmful greenhouse gases and pollutants. Finally, consuming less energy will reduce the energy resources that the United States needs to import from other countries, reducing United States dependence on foreign countries.

Ideally, individuals cut back energy usage by making changes in day-to-day behaviors favoring energy saving practices. These energy saving practices are made more plausible by encouraging individuals to focus their efforts on changing high energy consuming activities. This is a feasible scenario as it does not waste time on relatively small activities such as unplugging cell phone chargers or turning off a video game console that only reduce energy consumption by a little more than 0.25% of total household energy consumption (MacKay, 2009). However, it is not always easy to discern between the energy-saving practices that offer a significant reduction in energy consumption and waste production and the practices that offer a negligible change, or actually consume more energy. For example, many people believe that it is better to leave your car idling rather than turn it off and waste energy to turn it back on. In reality though this is only true if the car is idling for thirty seconds or less (Carrico, Padgett, Vandenbergh, Gilligan, & Wallston, 2009).

Currently there are enough fossil fuel reserves to keep up with current energy demand, in the form of electricity and fuels for heating and transportation for extended periods of time on the order of 10-50 years. In addition, any effects from waste production may not prove positive or negative for many years to come; however once the consequences caused by the excessive use of fossil fuels and the production of greenhouse gases can be easily felt, it will be difficult to reverse the effects. Therefore, changes need to be made now before society reaches a point of no return. This report looks at where an individual can make changes with the largest impacts without wasting time on ineffective practices. That is, this report evaluates energy saving proposals in high energy consuming areas to find where an individual can make the largest difference on reducing both energy usage and waste production with minimal disruption to everyday life.

There are a few problems and gaps left by other research articles, although many address proposals to conserve energy. The most common problem is that the research is written to target a specific demographic, such as those living in a city in a cooler climate, or on a specific topic and consequently is not easily accessible by the general population. This inhibits some of the previous research from being able to generalize to many locations, cultures, and demographics. Previous research, such as the study by Manning, et. al. has been inhibited by the specificity of its argument to energy efficient houses in a specific climate (Manning, Swinton, Szadkowski, Gusdorf, & Ruest, 2007). This report looks to make recommendations that are both comprehensive as well as transcend a variety of demographics to fulfill the following goals: reducing energy consumption, shrinking waste production, and being easily accessible to the general public.

To summarize the goals of the project is to answer these questions: *what can I, as an individual, do to conserve energy, reduce waste production, and make the world a better place?* In order to answer this question, this report will evaluate the minimum lifestyle changes required to have an impact, where to make these changes, and how to make them. The primary assumption is that these proposals do not involve the purchase of anything as an alternative to items currently owned as it is not within the scope of the report. We are evaluating the energy-saving potential of what the average person can do with what they already have, rather than making an investment in their energy future. Hence there are no recommendations to buy one car over another, instead there are suggestions to change future practices such as using certain motor oil over others when it comes time to change the oil in a vehicle. By suggesting minor individual lifestyle changes, we hope to show that an individual can make a difference and save the world one unit of energy at a time.

7. Background

The task of cutting energy consumption, and by extension reducing waste production, begins with a look at where energy comes from. As CO_2 emissions directly correlate with the source of energy use it is to identify the waste that each source is responsible for. After looking at the sources of energy which fuel vehicles, generate electricity, power machinery, and more it is imperative to analyze where the average individual uses the most energy. The determination of these energy intensive activities facilitates the decision of where to cut energy to make the greatest impact.

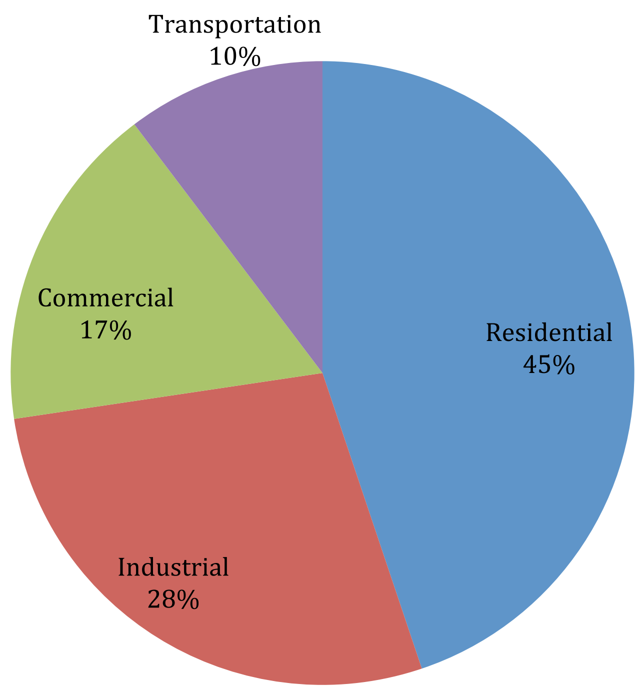

Figure 7.1: The distribution of energy consumption in the United States between the four sectors, commercial, industrial, transportation and residential with adjustments made to include personal transportation and actions pertaining directly to the food industry under the residential sector. The graph serves to highlight the opportunities available to the individual to decrease national energy consumption (U.S. EIA).

The residential sector, accounting for household and individual energy usage accounts for 45% of total U.S. energy consumption. This is compared to the industrial sector, accounting for 30%, the commercial/service sector accounting for 19% and non-household transportation consuming 11% of energy in the United States (Gardner & Stern, 2008). The residential sector consumes more energy than the entirety of the industrial sector. Therefore, those that make up the American population can significantly impact their personal energy consumption and waste production through the modification of personal behaviors to in turn positively affect the national energy consumption. These behavioral changes do not necessarily have to compromise one's way of life to make a sizeable impact. The reduction of energy consumption and waste production through behavioral modifications is important due to the various effects of waste production such as global warming and air pollution. However, it is the initial energy source that can make the largest impact on the amount of waste produced. Specifically fossil fuels are responsible for the production of more greenhouse gases than alternative sources of energy. For this reason, it is important to gain an understanding of where energy comes from as well as the waste produced by each of the primary energy sources.

7.1 The Sources of Energy and Waste Production

In order to study the quantity of energy produced and its associated waste products, this report will employ measurements of energy in one of two commonly used forms: British Thermal Units (BTU) and a Barrel of Oil Equivalent (BOE). A BTU is defined as the amount of energy required to increase the temperature of 1 pound of liquid water by exactly 1 degree Fahrenheit. A BOE is based on how much energy is in one barrel of oil and equates to approximately 6 million BTU. Each individual in the United States consumes around 156.097 million BTU per year. To put this in perspective, the average United States citizen consumes 26.02 barrels of oil equivalent in one year from a variety of primary energy sources (U.S. EIA, 2012a).

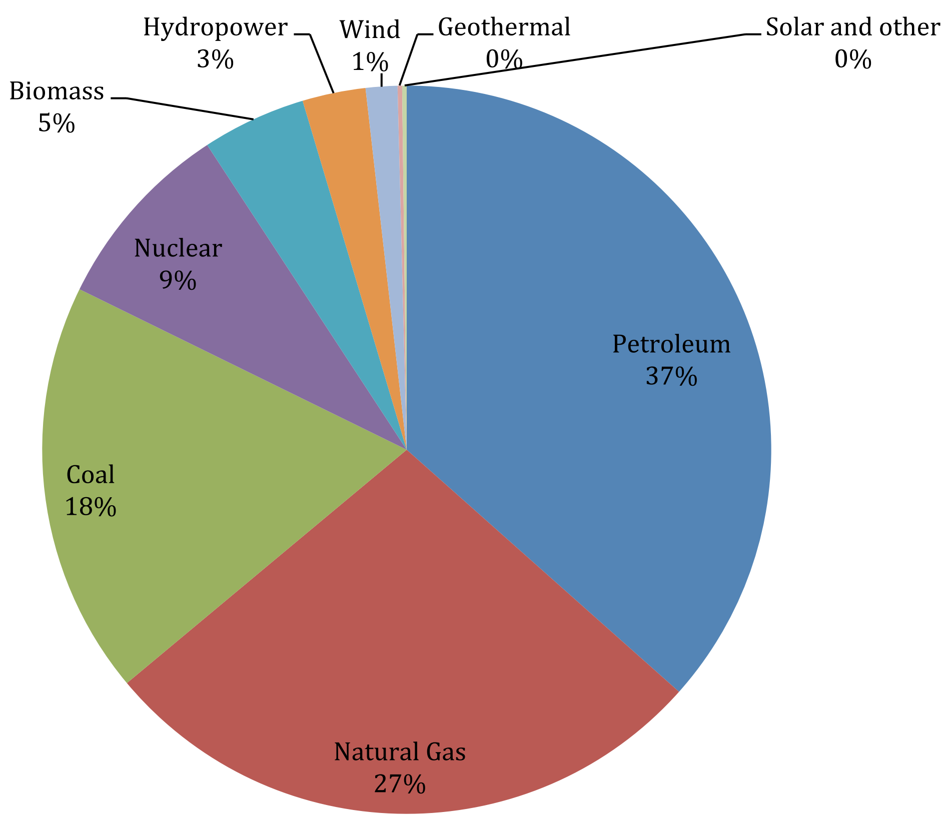

Figure 7.2: Distribution of the primary sources of energy that the United States uses for power generation, transportation and other end uses. Adapted from(U.S. EIA, 2013f).

When analyzing the production of waste, it is important to consider the origins of the consumed energy as it will have a significant impact on the amount and type of waste produced during energy extraction. For example, the carbon emissions will be different if a house is heated using a wood burning stove or natural gas. Figure 2-1 illustrates the total energy produced in the United States from each source. Oil, the source that makes up the greatest percentage of energy production worldwide, is responsible for waste production equivalent to 10.9 billion metric tons of CO_2 or 36% of the total carbon dioxide emission. Similarly, natural gas and coal each respectively produce 20% and 43% amount of carbon dioxide equivalent. In 2012, 30.3 billion metric tons of CO_2 were produced worldwide, the average US citizen contributed 17 metric tons to this total (IEA, 2012).

7.1.1 Oil

Oil is the number one source of energy consumed in the United States and the majority of the oil used powers the transportation sector in the form of gasoline and diesel fuels. It is also currently the largest source of energy used worldwide. Crude oil is primarily made up of hydrocarbons often mixed with other compounds such as nitrogen, sulfur, and oxygen. The current theory as to the origin of crude oil postulates that as organisms from millions of years ago died they were buried with sediment. This burial in the sediment led to extreme pressure under which the decomposition formed oil. Crude oil reserves exist all over the world in a variety of forms such as light oils, heavy oil, and oil sands. The various forms of oil require different processes and energy input to extract and refine crude oil into usable products.

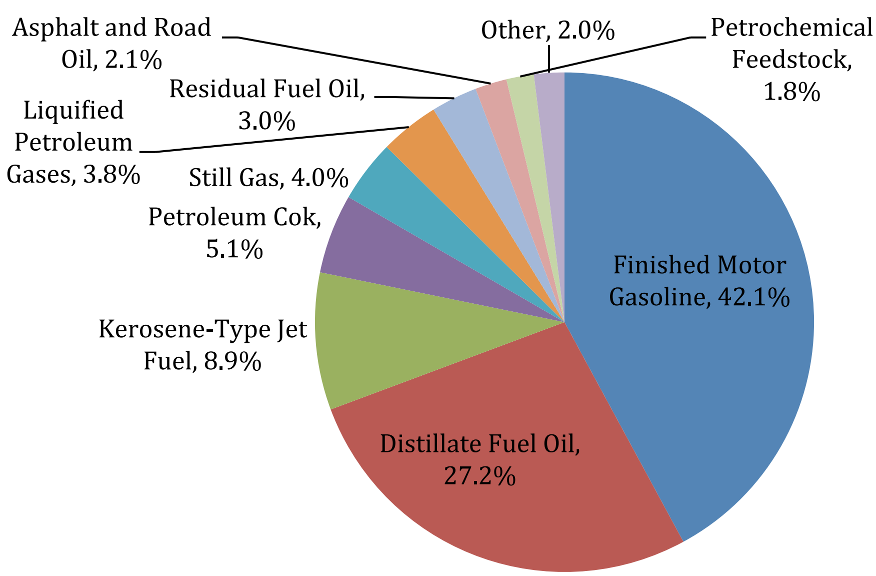

Figure 7.3: Distribution of end products produced from an average barrel of crude oil. The majority of crude oil is used to produce gasoline. The products grouped under other include products such as lubricants, petroleum products, special naphthas, aviation gasoline, kerosene and waxes. Adapted from: (U.S. EIA, 2013h).

The most common products of crude oil include gasoline which makes up the majority of crude oil products along with diesel fuel, kerosene-type jet fuel, kerosene and other products summarized in Figure 6.3 (U.S. EIA, 2013h). It is estimated that there are approximately 1,526 billion barrels of petroleum reserves available worldwide. Of the worldwide reserves about 1.7 percent reside in the United States, equaling approximately 26 billion barrels of oil (U.S. EIA, 2013d). Oil makes up 36% of the total energy that is consumed by the United States, however, the heavy use of this energy source comes at a price as petroleum also is responsible for the greatest contribution to carbon dioxide emissions in the United States. In 2012 the use of petroleum products in the United States account for 42.6% of total US CO_2 emissions equivalent to 2254 million metric tons per year of CO_2 (U.S. EIA, 2013k).

7.1.2 Coal

Coal is an energy-rich product of natural processes that is a primary source of energy by means of combustion. Similar to oil, the current theory as to how coal forms is through the compression and decay of dead organic matter over millions of years. As a result, the carbon from the organic matter gets pressed into a hard, amorphous solid made mostly of carbon. The long regeneration time for coal makes it a non-renewable resource. Coal is categorized based on the relative proportions of non-carbon compounds found in the coal; some common impurities include oxygen and sulfur. The age of the coal is correlated to the purity and energy density, with Anthracite having the most carbon purity, between 86% and 97% carbon by mass (U.S. EIA). The large amount of energy released as heat from the combustion associated with carbon means that coal is an excellent heat source upon burning; this, in addition to its abundance and resulting cheapness, makes coal a popular choice for an electricity-generating in the United States and rest of the world (U.S. EIA).

The extraction of energy from coal can result in as much as 15,000 BTU per pound, equivalent to 5.18 BOE per ton of high-purity coal, or about 14,000 BTU per pound, an equivalent of 4.83 BOE per ton of 78% carbon coal (Hong & Slatick, 1994). Coal is an abundant natural resource around the world. In the United States, nearly every state has coal reserves large enough to justify mining; Wyoming is the largest coal producer of the United States, producing 442.5 million tons of coal in 2010. Coal was responsible for 42.2% of the United States energy reserves used for electricity generation in 2011 (Hong & Slatick, 1994). Currently, the world supply of coal is not running dangerously low, and coal is unlikely to run out soon. The biggest concern with coal-burning is that it is a filthy resource; it burns dirty. In addition to the obligatory carbon dioxide emissions associated with other carbon-combustion energy sources, the sulfur and nitrogen impurities burn to release harmful “SO_x and NO_x” gasses. “SO_x and NO_x” is a class of many differently-oxidized sulfur and nitrogen compounds, respectively. SO_x and NO_x gases have been linked to environmental dangers, such as acid rain, that have a major negative impact on all of the earth’s ecosystems (Hong & Slatick, 1994).

7.1.3 Natural Gas

Natural Gas is a mixture of many different chemical compounds. The primary component of it is methane, however it also contains compounds such as ethane, propane, butane, carbon dioxide, nitrogen, water vapor, among other components (2007). Natural Gas is not a renewable resource, this means that it has a limited quantity and takes an extremely long time to form naturally. In 2004, it was estimated that the known reserves of natural gas remaining can last approximately 61.9 years (2007). Natural gas can be reacted with oxygen through a combustion reaction to produce carbon dioxide, water vapor, and energy. This is the typical way to extract energy out of the gas. Natural gas is typically used for: residential heating, industrial heating, other combustion based processes, and also as a supply for other chemical processes.

Approximately 1 million BTU of energy can be extracted per thousand cubic feet, that is equivalent to 0.17 barrels of oil per thousand cubic feet of natural gas (U.S. EIA, 2012a). Energy density is not the only important factor when considering primary sources of energy. Another important factor is the environmental impact, or the carbon emissions. Natural gas is actually quite clean for a fossil fuel with 1 million BTU of natural gas creating approximately 117 pounds of carbon dioxide, while 1 million BTU of coal and distillate fuel oil produce 200 pounds and 160 pounds of carbon dioxide respectively (U.S. EIA). When considering all the other resources that are typically used for heating, natural gas is one of the best resources as it produces relatively small amounts of particulate air pollutants and only moderate amounts of greenhouse gas emissions. This means it provides a good balance between the resources that are high in either particulates or greenhouse gas emissions and low in the other one (Brower & Leon, 2009). Overall, natural gas is a fairly clean resource that should be around for a while longer, however it is not limitless, so if consumption does not slow, alternatives will need to be found sooner, rather than later.

7.1.4 Nuclear

Nuclear energy is produced through the fission of atoms to produce smaller atoms and release energy. The most common fuel used in nuclear plants is uranium, specifically U-235. Although uranium is a fairly common metal the U-235 needed makes up less than 1% of uranium. Uranium is often mined in the form of uranium oxide and then converted into uranium hexaflouride. Before the uranium can be used as fuel pellets the uranium hexafluoride is enriched as it must contain between 3 and 5% U-235 to make explosions less likely. After the uranium is enriched it is converted to uranium dioxide powder, the powder is made into pellets before being loaded into the fuel assembly and eventually into the reactor (2014b). In the United States there are currently 65 different nuclear power plants and a total of 104 commercial nuclear reactors with 100% of the energy produced being put towards electricity generation and produce 9% of the energy used in the United States. Nuclear energy is not a renewable energy source as there is not a limitless supply of uranium or other fuels that can be used in nuclear power plants. However it is predicted that there is enough uranium worldwide for the next 100 years.

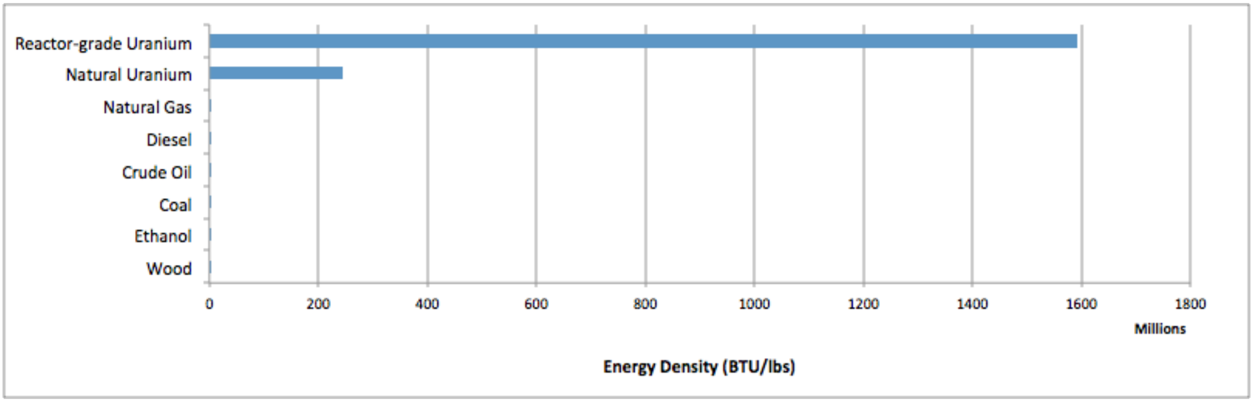

Figure 7.4: Illustration of nuclear power compared to other common sources of energy (Insight, 2009).

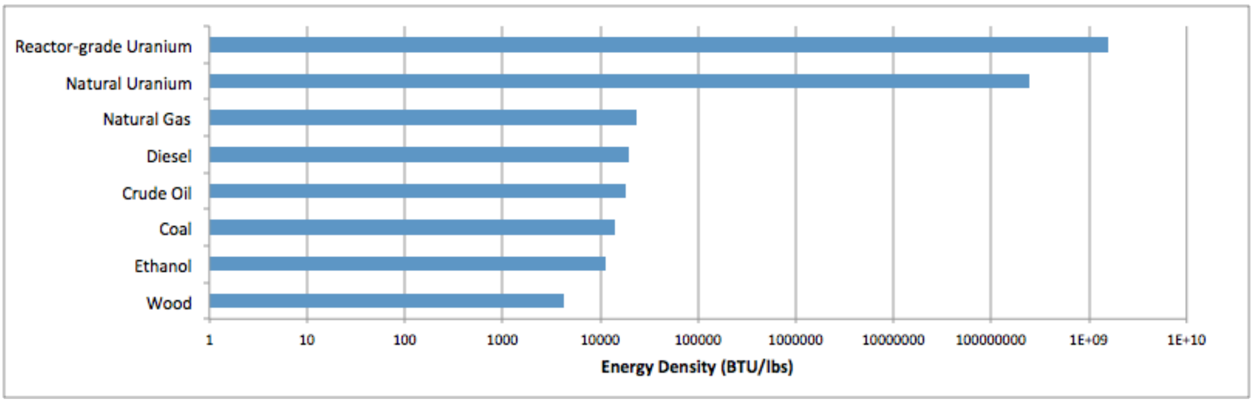

Figure 7.5: Illustration of energy density of nuclear power compared to other common sources of energy on a log scale (Insight, 2009).

An extremely large amount of energy can be produced from an extremely small amount of uranium. Specifically, the energy density for natural uranium is 245 million BTU per pound and 1.59 billion BTU per pound for reactor-grade uranium (Insight, 2009). To put this in perspective, one uranium fuel pellet, about the size of a pencil eraser, can produce approximately 21 million BTU or a little more than 3.5 barrels of oil (Nuclear Energy Insitute, 2014a). In the course of a year the nuclear facilities in the United States produce approximately 8.9 quadrillion BTU equivalent to 1.48 billion barrels of oil per year (U.S. EIA, 2012b). The waste produced by nuclear power plants contains radioactive material and therefore cannot be simply 'disposed' of but must be stored away carefully. Despite the radioactive waste nuclear power plants produce no carbon dioxide directly. Unfortunately, nuclear energy produces CO_2 emissions during the mining and refining of the uranium for the reactors as well as the initial construction of nuclear facilities. Despite this nuclear fuel is one of the cleanest forms of energy currently available.

7.1.5 Renewables

Renewables are a group of energy sources that can be sustained near indefinitely. This group of resources includes solar, hydropower, wind, and biomass. Biomass can be further broken down into wood, biodiesel, ethanol, etc. The major benefit of renewables is the ability to use them indefinitely without running out, unlike fossil fuels such as coal, oil, and natural gas. In 2012, these renewable energy sources accounted for approximately 9% of the overall energy usage in the United States nationally in 2012 (U.S. EIA). The different renewables each have their own individual uses, for example wood is often used to heat homes while hydropower is typically used to create electricity and biodiesel to fuel diesel automobiles.

Each renewable will have its own energy density and associated waste produced per unit mass. For example, wood is one of the most polluting options for heating a house due its high emission of particulate air pollution (Brower & Leon, 2009). In contrast, hydropower is an example of a renewable resources which has no direct emission of pollutants; however, the lack of pollution does not necessarily preclude other environmental impacts. Hydropower dams obstruct the natural migration patterns of fish and also impact water temperature and chemistry(U.S. EIA).

Other renewables such as ethanol and biodiesel are much cleaner than the pure gasoline or diesel counterparts, unfortunately they also produce less energy, meaning a balance must be found to optimize the amount of energy required and the subsequent waste produced (U.S. EIA). Wind energy has minimal impacts on the environment, however it does have some negatives associated with it. Wind turbines can be aesthetically unpleasing, result in the death of birds or bats that collide with the turbine, and on rare occasions catch on fire(U.S. EIA).

Solar energy is another well known renewable energy resource. Solar energy has many uses including heat and electricity production. Solar energy typically makes use of solar gatherers called photovoltaic cells which produce little no pollution or carbon emissions as well as having minimal environmental impact when placed on buildings. However, there are drawbacks such as the large surface area is required to get the energy required, the dependence on weather, the cost of modern photovoltaic cells, and the poor efficiency of such cells (U.S. EIA).

7.1.6 Electricity

Electricity is a secondary source of energy, rather than a primary one like those listed above. While electricity is the driving force behind most things we rely on in everyday life, it is not a direct source of energy. Electricity is the product of any and all of the above-listed primary energy sources. The modern power plant takes the physical, chemical, or nuclear reaction associated with the extraction of energy from a primary source and converts it into kinetic energy of an electromagnetic generator. Some primary sources, such as wind and hydroelectric power, can directly transfer kinetic energy from the medium to the generator. Other primary sources are used to create heat that vaporizes a working fluid, usually water, thus converting the potential energy contained in the primary energy source to internal energy in the resulting steam. The internal energy of the steam turns the shaft of a turbine to create the secondary electrical energy via the electromagnetic generator.

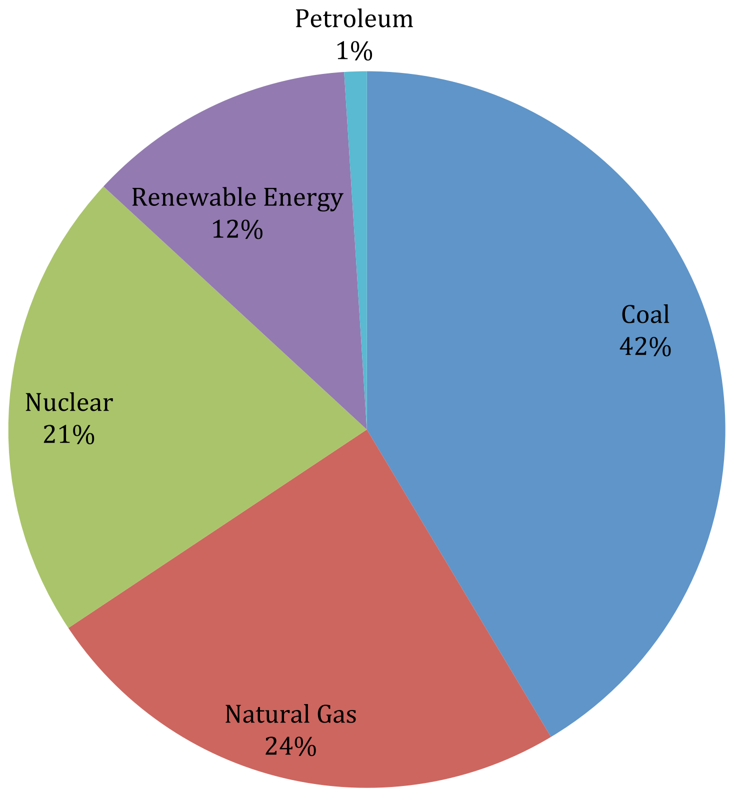

Figure 7.6: The respective contribution of each primary energy source to the production of electricity in the United States.

Electricity generation has its own potential for emission reduction. Non-polluting nuclear and renewable energy sources could take some of the energy share from natural gas and coal to reduce emissions.

7.2 The Uses of Energy

A primary issue when it comes to cutting energy consumption is sorting through fact and fiction to determine which activities actually conserve energy. It is then necessary to determine which activities are the most effective by exploring the areas where an individual uses the most energy on a day-to-day basis. After determining which areas are the "energy hogs," these top energy consuming activities were broken down to find where it is best to cut consumption within the specified areas.

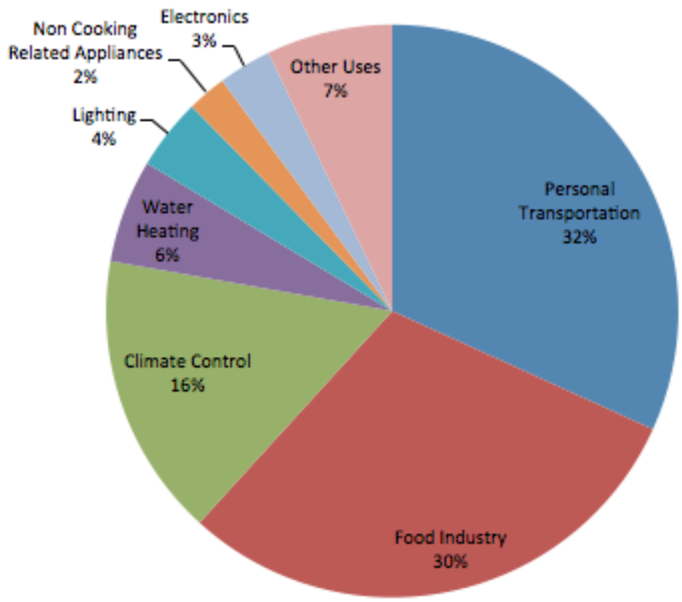

Figure 7.7: The distribution of where the average individual in the United States uses energy on a yearly basis(Canning; 2011).

Figure 7.7 shows the three largest areas of energy consumption by people in the United States. Personal transportation and the food industry each account for more than a quarter of the energy used in a person's daily life. Climate control, taken as the combination of space heating and space cooling, accounts for over 16%. Together these three sectors of personal energy use accounts for 78% of the total energy used by the individual. If everyone targeted those three specific areas to make changes in energy-consuming behaviors, a significant dent could be made in the overall energy consumed.

7.2.1 Transportation

People lead busy lives that require them to be at many different locations throughout the day, and to move between them in a short amount of time. There are many options available to travelers, including trains, automobiles, buses, walking, bicycles, airplanes, and boats. In recent years, the fuel efficiency of personal vehicles has improved, but there is still a significant amount of energy being consumed by everyone, every day, just to get from point a to point b. Personal transportation is powered almost solely by petroleum and accounts for the average consumption of 46.8 million BTU or 7.8 BOE in the course of a year for an individual. This number is affected by the fuel efficiency of the primary mode of transportation used, distances to points of interest, and how many trips are made to those points of interest.

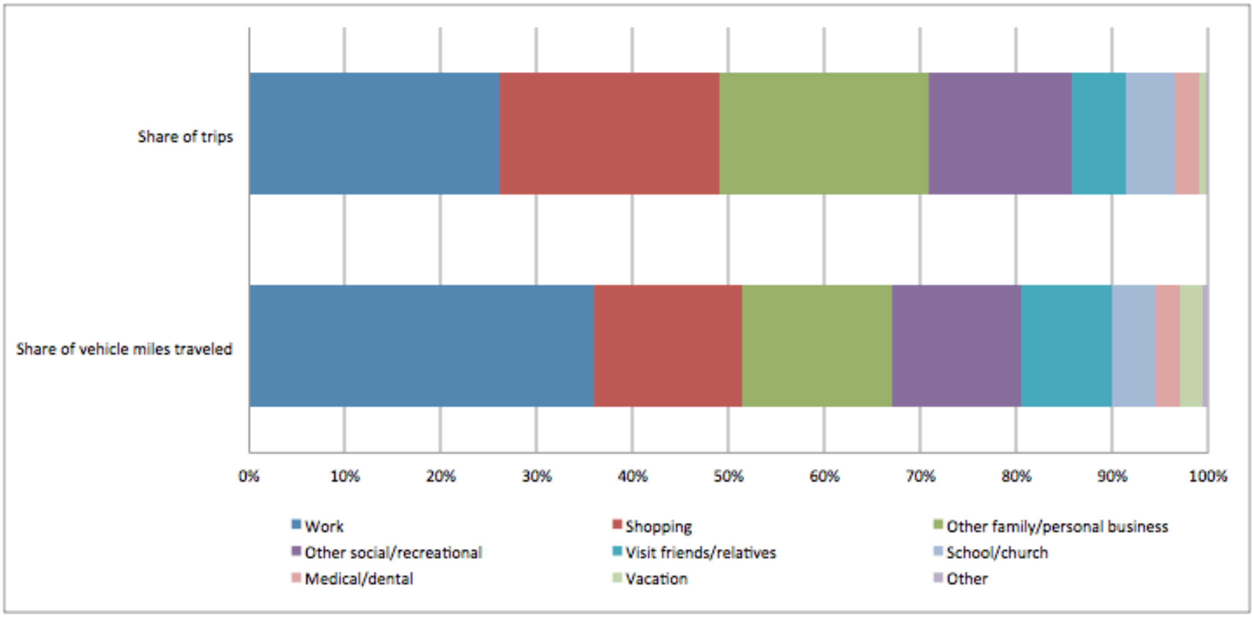

Figure 7.8: Comparison of the percentage of trips and the percentage of miles travelled for different purposes, primarily work, shopping and personal business for the average American(S. C. Davis, Diegel, & Boundy, 2013).

As seen in Figure 7.8 the main reasons why people use personal transportation is for work, shopping and personal business. Therefore it is easiest for individuals to make cuts in energy consumption within the transportation sector by making changes to how they get to work and places of interest. Personal vehicles, most notably large trucks, are responsible for a larger amount of energy expended per mile when compared to small cars, public transportation or biking. Despite the fact that there may be other more energy conscious methods of travel 86% of the US population relies on personal vehicles to get to work each day as seen in Figure 7.9.

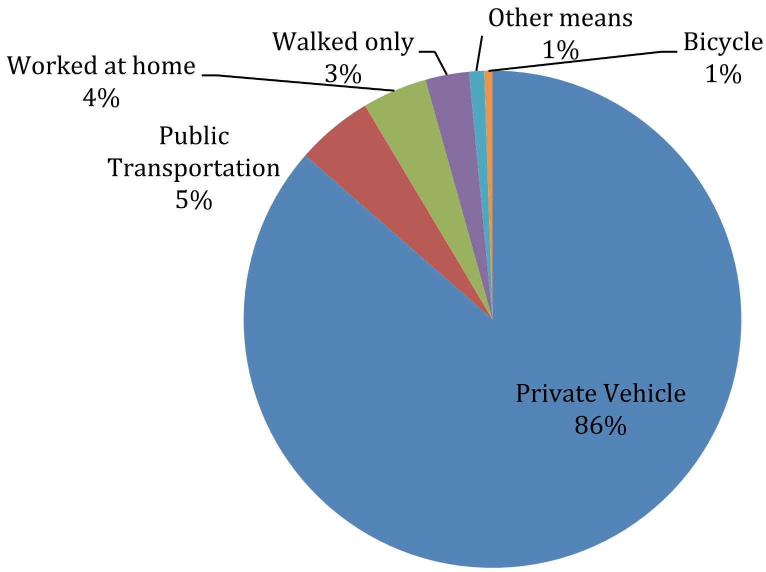

Figure 7.9: Distribution of methods of transportation used by the U.S. population to commute to work on a daily basis (S. C. Davis et al., 2013).

Table 7.1: Summary of the energy required for the primary modes of transportation based upon miles per gallon and BTU per passenger mile. Passenger mile is based upon the average occupancy of the various modes of transportation. For example a full bus will be much lower in regards to BTU per passenger mile than an empty bus although the miles per gallon will remain about the same (Litman, 2011).

Method of Transportation	MPG	BTU per passenger mile
Car	22.1	3578
Vans, Pickup Trucks, SUVs	17.6	4495
Bus	6.9	3697
Electric Light Rail	N/A	1152
Bicycle/Walking	0	0

Of the personal vehicles on the road the most common are small and midsized cars with an average fuel economy of 28.2 mpg and making up 46.8% of the personal vehicles bought in 2012. The second most popular vehicle on the road is traditional SUVs making up 20.9% of vehicles on the road but with an average fuel economy of 20.2 mpg (S. C. Davis et al., 2013). The financial cost as well as the energy cost is much greater for larger vehicles, especially when they are being utilized for a single passenger.

7.2.2 Food Industry

The food system is one of the most energy inefficient, yet necessary parts of our daily lives. The average American eats about 1,289,545 Calories of food per year, the energy equivalent of 5.114 million BTU per year (Pimentel & Pimentel, 2003). In 2002, the approximately 5 million BTU of food energy consumed in the United States required nearly 47 million BTU per capita to produce, or 13.54 quadrillion BTU, equivalent to 2.26 billion barrels of oil equivalent total (Canning). The inefficiency is inherent in the way the energy in the food we eat gets to the earth and into our food. Energy in our food comes indirectly from the sun: plants on earth use the sun's light energy to build glucose molecules and other molecules, which they can metabolize to build more complex molecules. Animals eat the plants, and can use some of the energy the plant has built for itself. Some animals eat other animals, and the energy from the plants passes another node in the food web. At each point, which represents a transfer of energy, a small fraction of the chemical energy available in the eaten organism is utilized by the metabolism of the eating organism; it should come as no surprise that enormous amounts of energy are required to grow/raise food, for only a little energy in return. For example, as many as 40 kilocalories go into producing one kilocalorie of beef protein (Pimentel & Pimentel, 2003).

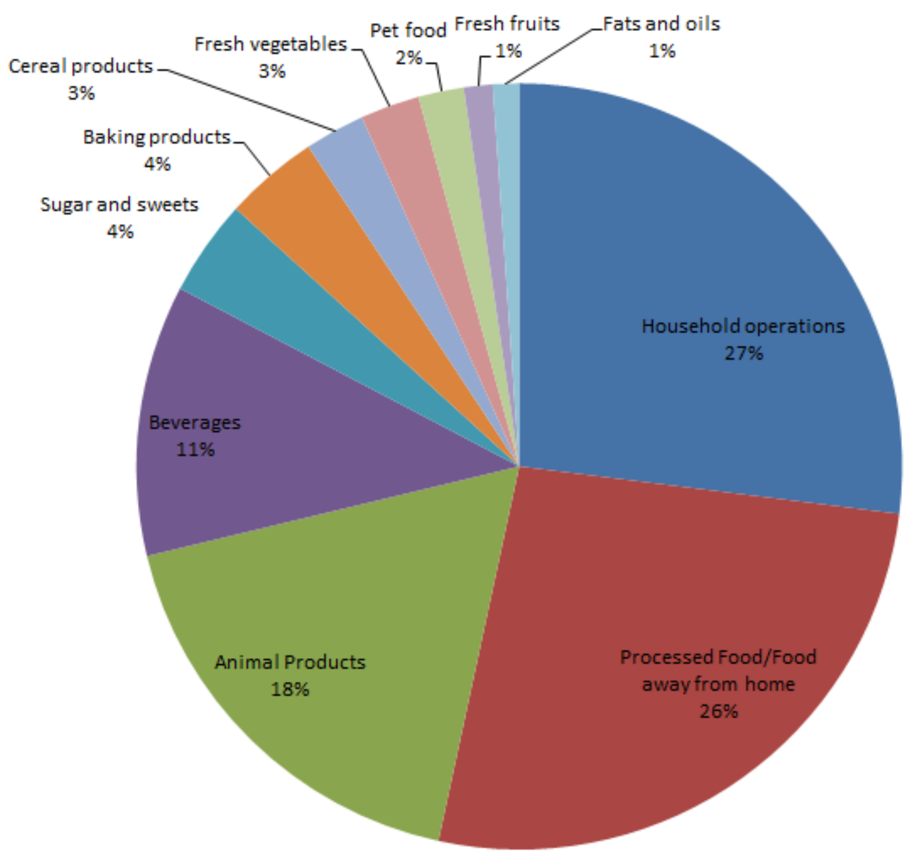

Figure 7.10: This chart breaks down the proportion of the total per capita food energy into different areas of the food industry, consolidated from the original source. Adapted from(Canning, 2010).

Household operations, which include household appliance usage, accounts for over 25% of the average American's food-related energy usage (Canning). When people are willing to pay for convenience, they may decide to eat at a restaurant, and restaurants incur their own energy costs. Food that gets processed also requires extra energy before it reaches the consumer, since it requires the same energy to produce the fresh food used in the industrial production while also incurring the added energy cost of the processing. Animal products are inherently more energy-intensive to produce, for the above-stated reason of the inefficiencies involved in the transfer of energy from one node of the food web to another. We can see in figure 6.10 the largest areas of energy consumption in the food system: the production of animal products for food, personal appliance use for cooking (household operations), the production of processed food, and the energy used in the food industry.

7.2.3 Climate Control

Climate control is the third largest area of energy consumption in the residential sector. It accounts for approximately 18% of the energy usage of a typical person, or approximately 47.88 million BTU per year, approximately 7.98 BOE. Climate control refers to the usage of energy for heating and/or cooling of residential space. The central idea of climate control is to make the residents as comfortable as possible. Since most individuals tend to have a comfort range between 61 and 75 degrees Fahrenheit, energy must be used to achieve the desired temperature (Molina, Lu, Sherman, & Harley, 2011). It requires a sizeable amount of energy to keep an average home at the desired temperature. It is estimated that on a per person basis, it takes approximately 31.1 million BTU per year to meet climate control desires in an average home size of 1971 square feet (Manning et al.) (U.S. EIA). There are many different energy sources for climate control. Heating tends to have sources such as wood, oil, or natural gas while cooling tends to use electricity to power air conditioners or fans. This means that even if two houses both use 70 million BTU per year, if they are using different resources they will have different carbon emissions and environmental impacts.

The diverse set of energy resources that can be used to power climate control makes an analysis of the waste production difficult. The different resources used result in a strange phenomenon where a 10% reduction in energy usage for one house will not necessarily eliminate the same amount of waste production as reducing a different house by the exact same amount of energy. The amount of waste produced also depends on the climate of the residence, since heating is more energy intensive, cooler regions tend to use more energy and thus produce more waste. According to the EIA, in 2011 the residential sector produced 274.74 million metric tons of carbon dioxide for space heating and 158.49 million metric tons of carbon dioxide for space cooling. The major limitation of saving energy related to climate control is in the ability to reduce the heating or cooling of a residence without sacrificing a high amount of comfort. Despite this limitation, the primary ways to look for energy saving in climate control are fairly straightforward.

7.3 The Effects of Energy Consumption and Waste Production

Waste production is an unavoidable companion to the usage of energy. Each source of energy has some sort of waste produced in processing the fuel into a usable energy. The amount of waste produced annually from factories, residences, and other sources of energy usage is enormous. In 2011, the United States produced 6,702 million metric tons carbon dioxide equivalent of greenhouse gases. Despite this fact, the greenhouse gas emission level in 2011 was 6.9% below the levels from 2005 (U.S. EPA, 2013). Although there is doubt human activity is to blame, data suggests that the concentration of atmospheric CO_2 is rising steadily. NOAA data collected at Mauna Loa, Hawaii indicates an approximate 0.11 ppm/year rate of increase of CO_2 in the atmosphere, even if total CO_2 emissions are falling (Tans & Keeling) Note that measuring the amount of CO_2 in the atmosphere is a difficult task, and is therefore likely to result in error; however, some objective scientific measurements shows a similar trend (Tans & Keeling) The burning of carbon-based heat sources produces a plethora of negative effects on the environment. Climate researchers have linked rising atmospheric CO_2 levels to negative effects on the environment, such as climate change, acidic seawater, and acid rain. Reducing waste emissions by cutting energy consumption is important for the good of our planet; not only will the negative environmental effects of excess waste be softened, but the life of the exhaustible resources currently used for the bulk of energy generation will be extended for a longer period of time as new renewable and sustainable sources of energy are developed.

7.3.1 Environmental Effects

Climate change, colloquially known as global warming, is one of the biggest effects that has been linked to rising levels of CO_2 in the atmosphere. Carbon dioxide acts as a greenhouse gas, i.e., it contributes to the greenhouse effect. The greenhouse effect is the trapping of the sun's radiated heat in the atmosphere; without it, life on earth would not be possible, but it comes at a price. Increased levels of greenhouse gases causes more and more of the sun's heat to get trapped in the atmosphere leading to an average rise in global temperatures. Rising amounts of CO_2 in the atmosphere not only contributes to the greenhouse effect, it also results in an increasing ocean acidity. Carbon dioxide in the atmosphere dissolves in ocean water to form carbonic acid, which creates increasingly more acidic aquatic ecosystems. This increase in atmospheric temperature and ocean acidity poses a veritable threat to the life that this world sustains. In order to noticeably slow the effects of global warming, greenhouse gas emissions need to be reduced immediately. The current goal is to keep global temperatures from increasing by more than 2ºC by reducing carbon emissions to 44% of the current worldwide level (IEA, 2012). As a bonus, dissolved CO_2 in ocean water will go down, or at least stabilize, if carbon emissions can be curbed.

Other detrimental effects from rising CO_2 and energy waste production include general air pollution, resulting in acid rain and smog. Acid rain is a direct result of the SO_x and NO_x gases mentioned previously. Similar to the rising acidity of ocean water acid rain disrupts the delicate chemical balance on which life relies. General air pollution and smog also affects life on earth, especially the quality of life. Cities with higher smog incidence rates are known to have higher rates of respiratory illness and inflammation amongst the people living there (U.S. EPA, 1999) Rising levels of CO_2 and other polluting agents in the environment have negative effects on the environment and the life forms living in that environment.

7.3.2 Economic Effects

The reduction of individual energy consumption benefits not only the environment, but also the individual. Using less energy reduces an individual's spending as well as their waste production. The economic benefits of saving energy are evident in a very simple way. Individuals pay for the amount of energy they use, if the amount of energy used is reduced then the cost of the individual's energy is also reduced. Making cuts to annual expenditures on energy is a beneficial factor, but there are economic impacts beyond the individual level. The reduction of energy consumption, especially from areas of energy use that have fossil fuels as the major resource, reduces the amount of imports that are necessary to meet energy demands. Reducing the country's reliance on foreign energy imports not only means less money spent on these outside fuel sources, but also less dependence on other countries. Energy independence for the United States would mean foreign countries cannot use energy resources as bartering chips or threats against the United States. Foreign countries also would not be able to dictate prices of oil and consequently gasoline. Saving energy in the residential sector could be the first major step towards energy independence for the United States. Energy independence would play a huge role in the global political and economical scenes. A lack of need for foreign energy sources would allow the U.S. more flexibility in the global political arena as potential energy ramifications would not be as detrimental to U.S. citizens.

7.4 The Role of the Individual

The key component required to save energy and reduce waste production is people. The ideas and strategies to save energy are great, but they are absolutely meaningless and ineffective without people putting them into place. The issue then becomes enacting these changes in daily lives to save energy and reduce waste. There are many different reasons why people may not put these strategies to use despite the environmental and economic benefits previously discussed. Some people may not know of a specific energy saving strategy in question; others may find it difficult to implement a strategy due to their own perceived analysis when weighing the potential benefits against the barriers and effort required. Some people believe their current lifestyle is easier to maintain so it must be the better option for them. There are also the people who may not necessarily be against enacting the change, but are too stuck in their ways. In many cases the individual will try to substitute a new habit for one that is already deeply ingrained in the person's mind and lifestyle (MacKenzie-Mohr & Smith, 1999).

To change the way people think and act with regards to energy consumption and waste production there is one major idea to keep in mind: the balance of benefit against detriment. As pointed out by McKenzie-Mohr, people have a natural tendency to gravitate towards changes that are easier to implement or that have a large benefit to them, or are changes they care about (MacKenzie-Mohr & Smith, 1999). It is very important to the individual making a lifestyle change or implementing a energy saving strategy to weigh the pros and the cons of the action. Numerous useful energy saving actions do not make it past this cost-benefit analysis, whether it is due to lack of knowledge on the topic, misinformation, or just not enough benefit to the individual to be worth the time of implementation. The question then becomes which energy saving and waste reducing activities are easy enough to implement without making a large impact on the individuals lifestyle while also having a considerable enough benefit to be useful, worthwhile, and truly capable of national or global implementation?

8. Results and Discussion

There are a multitude of ways that people can reduce their energy consumption and waste production. Many of these potential energy saving strategies will not likely have a large impact; however, there are still many others that can be very rewarding and save a noticeable amount of energy. How can individuals determine the effectiveness of a given strategy as well as the impact it will have on their lives? This report recognizes that different individuals have different lifestyles, and as such, suggestions are made with regards to which strategies will have the minimal amount of disruption on various lifestyles. The recommendations will be presented alongside data or mathematical analysis from various sources to help demonstrate the effects of the various strategies on energy consumption and waste production. Proposals are suggested with respect to the three high energy consuming areas previously identified: transportation, the food industry, and climate control.

8.1 Transportation

Transportation is one of the largest areas of energy consumption on both an individual basis as well as a national basis. Passenger vehicles alone consume 2.63 billion equivalent barrels of oil and produces 1.05 billion metric tons of carbon dioxide each year (U.S. EPA, 2013). A typical vehicle is responsible for producing 5.0 metric tons of carbon dioxide per year accounting for nearly a third of the carbon dioxide produced by a single person in a year. Thus, the ideal way to reduce the energy consumption and waste production in the transportation sector is to stop driving altogether and find alternatives such as biking or walking everywhere (S. C. Davis et al., 2013; Fuhr & Pociask, 2011). This is not always a practical solution and varies widely based upon location. For example, an urban setting provides options such as walking or public transportation in the form of buses or trains. In suburban and more rural areas public transportation is often not an option, but other alternatives, such as carpooling, and perhaps biking are available.

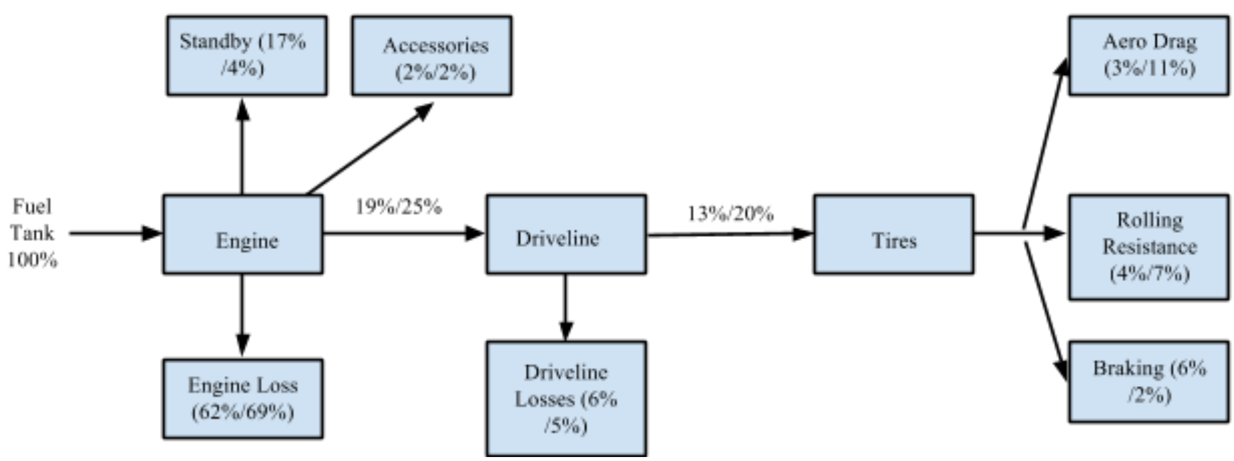

Figure 8.1: Summary of where energy is consumed in a personal vehicle. The first percentage listed is for city driving and the second is for highway driving (Press National Academies).

There are two categories for energy saving strategies. The first is making adjustments to individual driving habits through the modification of behaviors such as monitoring the air pressure in tires to make sure it is at an optimal amount or reducing highway speed to decrease air drag. Figure 8.1 illustrates where the energy used to power a passenger vehicle goes and is lost during the process, there are strategies to reduce some of these losses such as reducing the rolling resistance of the tires. The second category is finding alternatives to driving a personal vehicle all together through other available options such as public transportation or carpooling.

8.1.1 Maintaining Healthy Tires

The state of the tires on any given vehicle can ultimately have a significant impact on fuel consumption. This is due to a variety of reasons, most notably: the drag force, the mass, and resistance from the friction on the road and the heat dissipated in the tire. These terms are described and explained in more detail In the case of drag force, little adjustments can be made to reduce this force on the tires. The relationship between tire mass and fuel efficiency is measurable; according to Goodyear's technical center: if the weight of the tire is reduced by 10 percent then the fuel economy of the vehicle will increase by about 0.1 percent (Energy and Environmental Analysis Inc., 2001). However, the only way to reduce the weight of the tires is to alter the tires such as reducing the treads and making the tires themselves narrower. Making adjustments to the tires in such a way runs the risk of reducing performance and making driving more dangerous. Therefore, the reduction of rolling resistance yields the most promising and the safest, vehicle alterations to increase fuel efficiency.

Rolling resistance plays a large role in fuel consumption and consequently energy usage. Rolling resistance is defined as "The force at the axle in the direction of travel required to make a loaded tire roll" (2006). Generally, the impact that tires have to overall fuel consumption is calculated by its rolling resistance averaged over the lifetime of the tire on the vehicle (2006). The rolling resistance of a tire is not easy to calculate and can yield vastly different results based on the specific test run. Past studies have shown that for fuel efficiency to increase by 1% the rolling resistance needs to be reduced anywhere between 5 and 7% (Energy and Environmental Analysis Inc., 2001). Although some success can be achieved through the purchase of lower resistance tires there are other methods that avoid purchasing anything new. Generally the energy lost per mile due to rolling resistance is consistent across a variety of different makes and models though the percentage may vary.

The rolling resistance can be reduced through the manipulation of tire pressure. A study performed in 1980 by Schuring found that when tire pressure was increased from 24 psi to 29 psi the rolling resistance was reduced by 10%. Similarly for a tire with a tire pressure between 24 and 36 psi the relationship between pressure and rolling resistance is that for every drop in 1 psi the rolling resistance increases by 1.4%. When the pressure is below 24 psi the rolling resistance increases at an even greater rate (Press National Academies). Past surveys performed by the U.S. Department of Transportation's National Highway Traffic Safety Administration show that approximately 30 percent of all passenger vehicles have at least one tire that is under inflated by a minimum of 8 psi (Energy and Environmental Analysis Inc., 2001). The relationship between fuel consumption and tire pressure is approximately linear and can be summarized by saying fuel efficiency decreases by 0.3 percent for every 1-psi decrease in all four tires. This implies that nearly one third of all passenger vehicles are facing a 3.3% penalty in fuel efficiency (Energy and Environmental Analysis Inc., 2001).

8.1.2 Elimination of Unnecessary Idling

Idling, or leaving a car on while stopped, is a practice that is acknowledged to be an energy waster, but exactly how much fuel is saved by reducing the amount of time idling, and is it worthwhile? Whether it is a traffic jam or waiting for someone to run a quick errand into a store, most drivers have left a vehicle idling for some period of time. There are three primary situations where people idle. The first is to warm the engine of the vehicle for the good of the engine or the warmth of the passengers. The second is while waiting for something other than traffic. Finally, the third is idling in traffic. Due to the technological advance of vehicle engines less time is needed for engines to "warm up" and some current sources, such as the study completed by Carrico, suggest that a vehicle should be idle for no more than 30 or 60 seconds because after that point it is just wasting fuel. The first two idling behaviors are easily modified as newer cars do not require the engine to warm up and no damage is done from not idling, in addition idling is usually avoidable when waiting for someone or if going through a drive through. When waiting the vehicle can be turned off and a drive through can be avoided altogether. In the case of idling while in traffic it is a practice that cannot be helped due to safety concerns.

There are several myths associated with idling and they include: turning the engine on and off is hard on the starter, second, it is more efficient to idle then turn the engine off and back on again, third, idling is the best way to warm up the engine, and finally, idling does not cause damage to the engine. In reality idling more than 30 seconds is excessive and is simply a waste of fuel, also excessive idling causes engine wear and soot to build up which can in turn negatively impact the life of the engine (Curran, Settles, & Keel-Blackmon). In parts of some states unnecessary idling is actually illegal and could result in a fine. These states include Maine, Massachusetts, Maryland, New Jersey, Rhode Island, Utah, Hawaii and parts of Colorado, Missouri and New York .

In 2007 a study was completed by Carrico et. all in order to determine idling behaviors among the United States population. 1300 US drivers were surveyed and asked questions such as what the individual believed adequate lengths of time to idle were in order to save gas or warm up the engine as well as what personal idling habits were. The study found that on average Americans idle for approximately 16 minutes each day for three primary reasons: warming a vehicle, waiting for someone or something, and sitting in traffic. Results suggests that idling consumes approximately 0.57 gallons of fuel per hour and is responsible for emitting 11.11 lbs of CO_2 per hour (Carrico et al., 2009). Leveraging these results the study determined approximately 10.6 billion gallons of gasoline were consumed and 93 million metric tons of CO_2 were emitted by the total US population. This accounts for approximately 1.6% of total US CO_2 emissions.

Table 8.1: Summary of the average amount of idling per driver and their respective CO_2 emissions split into the three primary reasons for idling, to warm the engine or cabin, waiting and traffic. Adapted from (Carrico et al., 2009).

	min/day	Fuel Consumption per person per year (gallons)	CO2 Emissions per person per year (metric tons)
Warming	4.2	14.6	0.128
Waiting	3.7	12.8	0.113
Traffic	8.2	28.4	0.251
Total	16.1	55.8	0.493

As seen in Table 8.1 an average 55.8 gallons of gasoline per person per year is consumed from idling. The associated CO2 emissions equate to approximately 0.5 metric tons per person per year (Carrico et al., 2009). Unfortunately idling in traffic is near impossible to avoid or reduce as it is generally unplanned and turning off the engine in traffic poses a potential safety hazard. In the case of warming up a vehicle or waiting in a parking lot, idling can be completely omitted in order to save energy and reduce carbon emissions. Therefore idling practices can be easily reduced nearly 50% by not prewarming a vehicle and turning a vehicle off while waiting in a parking lot. Other more specific strategies to reduce idling include not using a remote vehicle starter, walking into the business rather than using a drive-through and turning off one's vehicle when waiting. If idling was reduced to the EPA recommendations, requiring Americans to idle for no more than 30 seconds then the U.S. CO_2 emissions could be reduced by nearly 0.241 metric tons per person per year. This makes up approximately 1.4% of the CO_2 emissions generated by a single individual in the course of a year (Carrico et al., 2009). The average energy savings per person generated from omitting unnecessary idling is equivalent to 7.25 million BTU per year or 1.2 barrels of oil. More specifically: for each hour of idling avoided an individual can save 0.57 gallons of gas and prevent the release of 11.11 pounds of carbon dioxide into the atmosphere (Carrico et al., 2009)

8.1.3 Turning off In-vehicle Air Conditioning

Air conditioning is vehicular function that is responsible for drawing a large amount of power. The load that the air conditioning places on the vehicle can be comparable to the same engine power used to move a mid sized vehicle at a constant 35 mph. Air conditioning units require between 3-6 kW to operate (Rugh, Hovland, & Andersen, 2004) It is estimated that air conditioners are used between 43% and 49% of the overall time an individual is in a vehicle for either cooling or dehumidifying purposes; however this does vary immensely based upon the climate, temperature, time of day and certain vehicle characteristics such as color (Farrington & Rugh, 2000).

In order to test fuel efficiency under various operating conditions, such as the use of air conditioning, vehicles are run through what is known as a cycle. A cycle is a driving pattern with specific parameters such as average speed, acceleration, ambient temperature and whether or not the air conditioning is on used by government and research agencies to test the efficiency and performance of vehicles under various operating conditions. Specifically the SC03 cycle is used to find the load the air conditioning places on the vehicle's engine from vehicle start up. The results of the SC03 cycle can then be compared to the Federal Test Procedure (FTP) cycle and the US06 cycle which are both relatively similar. An important aspect to remember concerning the use of the air conditioner in a vehicle is that the degree it is used is directly dependent on temperature and humidity and these variables in turn have an effect on the load put on the engine.

Table 8.2: Summary of the specific aspects in each respective cycle used for vehicle testing. SC03 is specifically used for testing of air conditioning as opposed to the Federal Test Procedure (FTP) and US06 cycles. Adapted from (Farrington & Rugh, 2000).

	FTP	SC03	US06
Time (s)	1877	594	600
Max. speed (mph)	56.7	54.8	129.2
Max. acceleration (mph/s)	3.6	5.1	8
Distance (miles)	11.1	3.6	8
Contribution to total emissions value	35%	37%	28%

Using the various cycles described in Table 8.2 tests have determined that if an air conditioning unit is running in a conventional vehicle on average it will decrease fuel economy by 4-6 mpg (Farrington & Rugh, 2000; Rugh et al., 2004). In the course of a year, each vehicle consumes approximately 62 gallons of gasoline for the sole purpose of running the air conditioning in a vehicle. Additionally, the electrical load from the air conditioning system is responsible for approximately 37% of tailpipe emissions and the use of air conditioning increases carbon emissions by 1.6 grams per mile (Farrington & Rugh, 2000; Levinson et al., 2011). It is estimated that the United States as a whole produces approximately 62 million metric tons of CO_2 per year due to in vehicle air conditioners alone (Rugh et al., 2004).

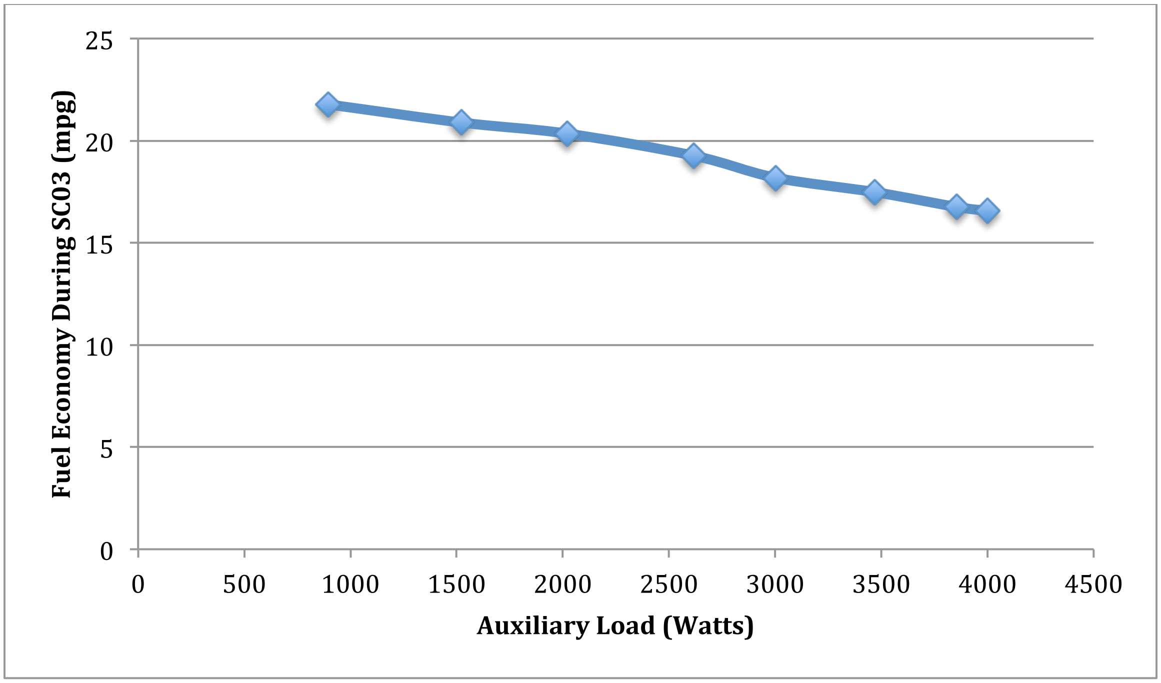

Figure 8.2: The figure demonstrates the impact that an auxiliary load, in this case an air conditioner, can have on the fuel economy of a vehicle based off of the data collected when running the vehicle through the FTP and SC03 cycles. Adapted from (Farrington & Rugh, 2000)

In vehicle air conditioning is estimated to consume approximately 7.1 billion gallons of gasoline in the US each year. This is equivalent to 10% of the crude oil imported into the United States. Therefore by reducing the use of air conditioning by 50% approximately 5% of crude oil imports can be reduced (Johnson, 2002). The overall impact of the air conditioning on the fuel economy of a vehicle varies based on other factors such as speed and the load an engine is designed to handle. In general though it can be estimated that fuel consumption will increase between 0.52 and 1.20 gallons per 100 miles. This can also be looked at in such a way that a vehicle with the capability of going 400 miles on a tank of gas will consume between 2 and 5 additional gallons of gasoline when the air conditioner is in operation. Ultimately, the load the air conditioning places on the engine increases fuel consumption by 19.8% .

8.1.4 The Costs of Aggressive Driving

Aggressive driving, defined as high acceleration and deceleration, is a culprit of increased fuel consumption. There are many factors of aggressive driving that affect fuel consumption. For example, whether the aggressive driving is associated with the higher speeds of city or the lower speeds of city driving affects the fuel efficiency as well as the horsepower of the specific vehicle. In a study performed by the California Resources Board, 17 vehicles were run on four different courses in order to simulate normal city driving, aggressive city driving, normal highway driving and aggressive highway driving. The Federal Test Procedure (FTP) simulated normal driving and the Unified Cycle (UC) simulated aggressive driving in a traditional city setting as well as a highway setting.

Table 8.3: Summary of the parameters for the cycles used to evaluate the impact of increased acceleration and deceleration on fuel efficiency. The FTP (City) Cycle represents standard city driving and is compared to the UC cycle with increased acceleration and deceleration. Similarly the FTP (Highway) Cycle represents conservative highway driving and is compared to the US06 cycle with increased values for acceleration and deceleration. Adapted from (Energy and Environmental Analysis Inc., 2001).

	FTP (City)	UC	FTP (HWY)	US06
Average Speed (mph)	21.18	24.63	48.27	48.37
Maximum Speed (mph)	56.70	67.20	59.90	80.30
Average Acceleration (mph/sec)	0.89	1.15	0.384	1.383
Maximum Acceleration (mph/sec)	3.30	6.90	3.20	8.40
Maximum Deceleration (mph/sec)	-3.30	-8.80	-3.30	-6.90

The parameters used for each test are summarized in Table 8.3 where the acceleration and deceleration for the UC Cycle was more than twice that of the FTP (city) cycle. Similar test parameters were used in low speed experiments conducted by Berry. For example the test performed demonstrated that in neighborhood driving fuel consumption is impacted more by speed than increased accelerations. In the case of city driving acceleration plays a larger role than speed in the amount of fuel consumed increased. Finally, in the case of highway driving speed is a larger determining factor in fuel consumption than acceleration but both can make a noticeable impact on fuel economy (Berry, 2010).

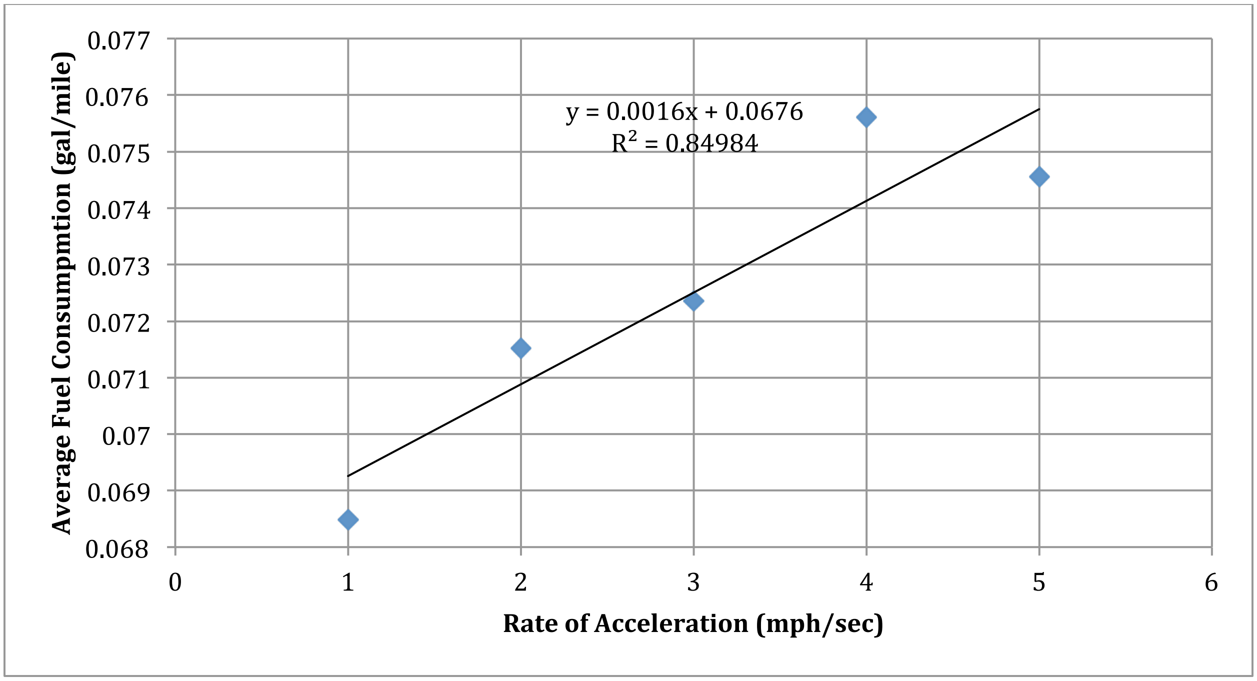

Figure 8.3: The approximately linear relationship between the rate of acceleration and the associated fuel consumption demonstrating the effect that increased acceleration has on increasing the amount of fuel consumed. Adapted from (R. Jones, 1980).

The negative impact that aggressive driving has on fuel economy is further supported by the results obtained by the study completed by the California Resources Board. In a city driving setting, the two compared driving cycles, for conservative and aggressive driving, varied in fuel economy by a maximum of 15%. The penalty for aggressive driving on the highway ranges from 25% to 40% penalty on fuel consumption. The vehicles tested showed a much greater difference in fuel efficiency between traditional and aggressive driving with fuel consumption differences between 25 and 48%. Therefore one of the easiest ways to conserve energy when it comes to driving practices is to drive less aggressively. Ultimately, reducing rates of acceleration and deceleration can reduce energy consumption by 48%, depending on initial driving habits. For the average driver energy and emission savings can be expected between 5% and 40% or an average of 0.0061 BTU per mile.

8.1.5 Reducing Speed

In a fast paced world, it is difficult to slow down regardless of some of the benefits; however the benefits of speed reduction have been explored and utilized at the national level. During the 1973 oil crisis a lack of gasoline resulted in the creation of the Emergency Energy Highway Conservation Act. The law enacted a national maximum speed limit of 55 mph in hopes to save between 0.2% and 3% of annual fuel consumption (U.S. GAO & Gaffigan, 2008). In a modern day setting it is estimated that the enforcement of a national 55 mph speed limit could save the United States between 175,000 and 275,000 barrels of oil per day. Although the ideal speed for greatest fuel economy varies based upon the vehicle though it is generally between 30 and 60 mph (U.S. GAO & Gaffigan, 2008).

Driving speed plays a large role in fuel economy due to the forces acting on a vehicle at any given time. At slower speeds fuel is primarily consumed due to general engine friction, motor oil can help ease the friction as well as operation in the highest gear to reduce the average engine speed. At higher speeds the greatest force the energy from the engine must overcome is air drag. As speed increases so does the air drag impact on the vehicle. There are only two ways to reduce the drag force: increase the vehicle's aerodynamics (by removing roof racks for example), or to reduce traveling speed. Figure 8.4 summarizes the effects that various forces have on vehicle fuel consumption and the associated ideal velocity.

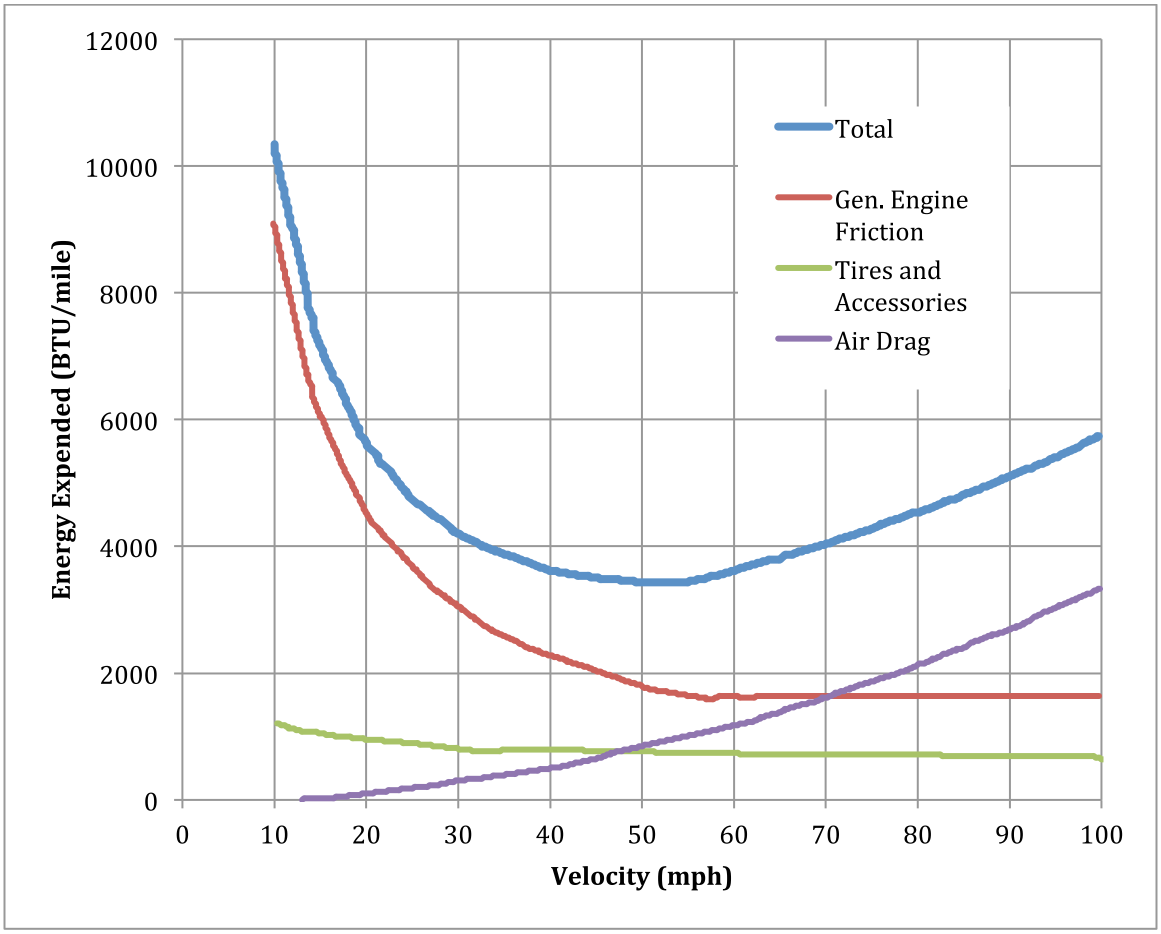

Figure 8.4: Summary and simplification of the effect aspect have on vehicle fuel consumption relative to speed. The blue line represents the overall relationship between speed and energy and then broken down into the primary forces that affect this relationship, specifically Engine friction, energy lost to the tires and accessories and the air drag acting on the vehicle. Adapted from (Ross, 1994).

According to experiments completed by Ross et al, the most efficient cruising speed is approximately 50 mph as illustrated in Figure 8.4. There are other compounding factors attributed to driving fast that also harm fuel economy other than the explicit engine friction and air drag described. For example, tire treads also wear faster at higher speeds and increases the likelihood of uneven wear on the tires. In addition, higher speeds also have the problems on increasing engine wear costing about 10-15% more in maintenance fees for those that normally drive at 75 mph instead of 55 mph (Ahluwalia, 2008). Based upon studies cited by Gaffigan's letter to Senator Warner advocating a new modern national speed limit, for every 5 mph speed is reduced fuel economy will increase by between 5 and 10% (this is only applicable for speeds over 35-45 mph). These saving from reducing highway speed from 75 mph to 50 mph result in savings of 0.0043 BTU per mile (U.S. GAO & Gaffigan, 2008).

8.1.6 E-commerce

E-commerce, the act of buying goods using websites such as Amazon.com or Ebay.com and having goods delivered directly to one's house, is a topic of energy conservation that has been studied yet remains somewhat inconclusive. The supposed benefit is that the individual does not need to drive to a store to purchase goods, thus potentially saving energy. There have been several studies completed over the past two decades concerning the benefits and disadvantages associated with e-commerce. One such study completed by Matthews et. al. in 2001 looked exclusively at the environmental and economic impacts of e-commerce in relation to the book publishing industry (Matthews, Hendrickson, & Soh, 2001). Another study conducted by Weber et al looked at the energy consumption of buying a flash drive through traditional means or through e-commerce (Weber et al., 2008).

The energy expended for traditional methods of retail compared with e-commerce can be approximated using a study conducted by Matthews et. al. In this study the environmental and economic costs for traditional methods of retailing books were compared to the estimated costs of e-commerce for $1 million worth of books. The study looked at the path taken by published books and calculated the energy consumed at each point: the printer, national warehouse, regional warehouse, retailer, and either to the consumer or back to a warehouse to return unsold copies. In the instance of e-commerce where print books are delivered directly to the consumer (note that this is not referring to electronic copies of books) the book follows a slightly different path: the printer, e-commerce warehouse, regional logistics center, and then the customer. This study assumed that 35% of books in traditional book retailing were returned to the regional warehouse. Matthews et. al. calculated the energy found the energy costs associated with each stage of the process: trucking, production, packaging, passenger trips to the bookstore, and passenger fuel. For e-commerce the energy consumed was based off trucking, air shipping, production, packaging and delivery trips. Ultimately the study found that approximately 28.4 billion BTU were consumed in the ecommerce trial while 31.3 billion BTU were consumed for traditional book retailing. Comparatively, an estimate of 2000 million tons of CO_2 are emitted in traditional retailing and e-commerce emits only slightly less at 1963 million tons of CO_2.

Similar to the process of book retailing the general process of retailing a flash drive starts with the manufacturer, leads to the wholesale warehouse, retail warehouse, the retail store and ends at the consumer level. The path of e-commerce also begins with the manufacturer followed by a warehouse, the collecting and sorting distribution followed by deliver directly to the consumers home (Weber et al., 2008). The energy consumed for each stage of the process was calculated and then compared between traditional retail, retail with inclusion of a retail warehouse, baseline e-commerce and e-commerce with use of air shipping. E-commerce on average cost 10.4 thousand BTU less than traditional retail on a per item basis. If retail includes a retail warehouse then e-commerce averages about 28 thousand BTU less than retail, however, if express air shipping is used then e-commerce is only about 5 thousand BTU less than retail on a per item basis. It is important to note though that the standard deviations calculated for each mode overlapped so traditional retail is not necessarily the more efficient option. In addition, to put the best case scenario in perspective 5 thousand and 30 thousand BTU are equivalent to 0.0008 and 0.005 barrel of oil equivalents respectively.

In another study completed in 2007, Lan Yi and Hywel Thomas did a review of the current research of the environmental impact of e-commerce (Yi & Thomas, 2007). This review included comments concerning the previously mentioned studies concerning e-commerce as well as many others. One of the most notable attempts to quantify the environmental effects of e-commerce was conducted by the Digital Futures project in 2001. It was a joint project with input from 14 corporate partners, three government departments and eight think tanks/research organizations. The result of the joint project was inconclusive due to the complexity of the relationships, as well as many variables that are "unidentified, unpredictable or immeasurable." (Yi & Thomas, 2007)

Therefore there exists some evidence that the use of e-commerce can save a small amount of energy although the savings can be significantly impacted based upon shipping speed as well as the amount of items shipped or brought together. Analysis done by stores such as Patagonia showed that when they used traditional slower methods of shipping, using boats and rail as opposed to air freight, the transportation energy costs accounted for 6%, approximately 400-500 BTU per ton mile, of the total energy needed to create and transport the product. Alternatively, when overnight shipping was used and required air freight and trucks the percentage of the energy used for transportation increased drastically to 28%, approximately 14000 BTU per ton mile (Romm, Rosenfeld, & Herrmann, 1999). Ultimately though, based upon the aforementioned studies, e-commerce results in nearly negligible energy savings for the individual, compared with driving to a store to purchase goods.

8.1.7 Public Transportation

One of the easiest alternatives to take in consideration when attempting to reduce energy consumption and waste production is to find an alternative to driving. Walking and biking become less of an option as the distance from one's destination increases; however, public transportation is a viable option that exists within less than a mile of 51% of the American population as of 2001(Bailey, 2007). The savings from public transportation vary based upon what mode of public transportation is taken and what the options are in a given area. Some of the options available for public transportation include the use of diesel buses, diesel commuter rails, electric commuter rails, heavy (high capacity) rail, and light (low capacity) rail. In 2004, public transportation was responsible for the consumption of approximately 856 million gallons of gasoline, considering the amount of people taking transportation and the miles travelled the passenger miles per gallon is approximately 57 mpg compared to the average fuel economy of 23 mpg for a passenger vehicle in the United States (Bailey, 2007).

Table 8.4: Summary of the amount of energy it takes to power various forms of public transportation assuming they are full (BTU per seat mile) and at the average occupancy rate (BTU per passenger mile). An average of the energy taken to power a light duty vehicle (the typical automobile driven by people) is also included for comparison purposes. Adapted from (McGraw, Shull, & Miknaitis, 2010).

Vehicle	BTU per seat mile	Average Occupancy Rate	BTU per passenger mile
Diesel Bus	1028	0.28	3671
Diesel Commuter Rail	709	0.30	2363
Electric Commuter Rail	510	0.30	1700
Heavy Rail	789	0.47	1679
Light Rail	950	0.37	2567
Light Duty Vehicle	1220	0.32	3812

The values in Table 8.4 assume that the modes of public transportation are filled to their average capacity ranging from 28 to 47%. This means that the savings from public transportation have the ability to increase if more individuals take advantage of public transportation (McGraw et al., 2010). There are additional factors to consider when calculating the overall savings from the use of public transportation and the savings increase in larger increments as more individuals take part in the system. It is estimated that the primary savings of using public transportation in lieu of privately owned vehicles is compounded by the savings gained in the reduction of congestion from decreased vehicles on the road. If public transportation is expanded then further savings could be gained from restructuring the location of public transportation points although some savings would be negated by increased fuel usage.

At current usage rates the U.S. Committee on Transportation and Infrastructure estimates that public transportation saves the United States approximately 4.2 billion gallons of petroleum/year and reduces carbon dioxide production by 37 million metric tons as opposed to if all those currently using public transportation switched to driving personal vehicles. The reduction in carbon dioxide emissions is equivalent to about 20 lbs of carbon dioxide per person per day accounting for just over 2 metric tons of carbon dioxide per person per year (U.S. Congress House, 2008). To further put this in perspective, an individual driving one mile in a standard vehicle is responsible for producing 1 lbs of carbon dioxide (T. Davis & Hale, 2007). Ultimately the transition from driving to public transportation has the potential to save at least 141 BTU/mile and depending on the mode of transportation the savings could increase. In addition, public transportation yields the promise of increased savings as more individuals take advantage of the current public transportation infrastructure.

8.1.8 Carpooling

Similar to the creation of the national speed limit the event that made carpooling a more popular alternative to driving alone was the oil crisis of 1973. Since then, carpooling has evolved into three primary subgroups: informal carpooling/slugging, pre-arranged carpooling, and real-time carpooling. The first of the three is becoming a more common practice in urban areas such as Washington D.C, Los Angeles or San Francisco. There are designated pickup points where drivers and riders meet up at designated times in order to make use of the highly occupied vehicles (HOV) lane. Pre-arranged carpooling is traditional carpooling though unlike in 1973 internet services exist for people to find others travelling similar routes. Finally real-time carpooling uses service providers to provide people with rides using specified parking lots, call boxes or cell phones so that those interested in getting rides can call or meet at a certain place and be quickly matched up with a driver. Oftentimes the latter two forms of carpooling are grouped together (Handke & Jonuschat, 2013).

The benefits from engaging in carpooling include the energy savings as well as it allows those without a vehicle to gain more mobility without purchasing a vehicle. In addition, it allows those with vehicles to save money without significantly changing driving habits through the sharing of something as simple as filling up the gas tank {Duncan, 2010}. In regards to economic and energy savings it is estimated that carpooling can save about 24% of energy consumption in an urban setting. When informal and prearranged carpooling systems are put into place they do take away from individuals who would otherwise use public transportation and therefore results in increased congestion on the highways and therefore have some negative side effects. The informal carpool system is currently responsible for saving between 183 million and 428 million BTU of energy per day in the United States (Dorinson, Gay, Minett, & Shaheen, 2009).

According to a study completed by Jacobson et al the fuel savings were calculated by looking at what would happen if one passenger was added to every 100 vehicles, every 20 vehicles and every 10 vehicles (Jacobson & King, 2009). The study found that if one passenger was added to every one hundred vehicles 800 to 820 million gallons of gasoline would be saved per year in the United States. If this was increased to one passenger per every 10 vehicles then the US would save between 7.54 and 7.74 billion gallons of gasoline per year assuming no additional travel is required to pick individuals up from different locations (Jacobson & King, 2009). Although these numbers look nice, what significance does it hold on an individual basis?

Unfortunately there is limited data on the per mile and per person energy savings accumulated from carpooling. Looking at it from a generalized perspective though the amount of energy saved is just a little less than the energy it would take to drive a secondary vehicle due to the slight increase of weight. If members of the carpooling can be picked up within a reasonable distance of the route then it is not unreasonable to assume that individuals save approximately 0.04 gallons of gas for every mile driven in a carpool. Split between the driver and a single passenger the savings are equal to 0.02 gallons saved per mile per person assuming an average fuel economy of 23 mpg. If a vehicle is fuel with one driver and 4 passengers then each person participating saves approximately 0.032 gallons of fuel per mile driven in the carpool. This is promising strategy for anyone living in any situation. It is an effective strategy for a group of individuals living in or just outside of a city who are all commuting to the same place or those living in a rural environment. The only requirement is to find another individual with a similar commute.

8.1.9 Telecommuting

Telecommuting, the act of working from home, is not an option for everyone, but it is the most efficient energy saving activity in the transportation sector. Unfortunately, the exact energy savings from telecommuting are difficult to compute. Some of the compounding variables include the number of personal trips made outside of work as well as reduced congestion leading to increased highways speeds if telecommuting becomes a more common practice (Romm et al., 1999). Another compounding aspect of telecommuting is the energy expended in the house for heating throughout the day thus somewhat negating the energy savings from telecommuting itself. For example, during the heating season CO_2 emissions are greater for those who telecommute three days a week compared to those who do not participate in telecommuting at all. Alternatively, during the summer months those that telecommute for three days out of the work week are responsible for reducing their CO_2 emissions as they consume less energy at home from heating and cooling then the trip to work (Kitou & Horvath, 2003).

According to a study completed by Mokhtarian those participating in telecommuting droven an average of 39.8 miles less per weekday. The average reduction of miles driven was found using multi-day travel diary surveys in order to record both work and non work related driving. The study found that both commute and non commute travel decreased among those participating in a telecommuting program (Mokhtarian, Handy, & Salomon, 1995). The studies were specifically conducted in California, Puget Sound and the Netherlands, on average individuals saved between 14% and 75% of miles driven. The savings in the Netherlands was much less than the other two surveys conducted, therefore it is probable that savings are closer to 75% than 14% on telecommuting work days.

Other studies analyzed by Mokhtarian included a survey conducted in Arizona concerning the fuel savings of telecommuting. The various studies estimated gallons of fuel saved per telecommuting occasion by dividing the average miles saved by the average amount of miles driven and most used 24-26 mpg as the average fuel economy. This resulted in a range of estimated savings between 0.9 and 2.2 gallons saved per telecommuting occasion, however, when the increased energy used in the home is factored in slight adjustments are made resulting in decreased in estimated savings. Specifically in the Puget Sound study when telecommuting was put into place household energy usage increased by 0.7 million BTU per year (Mokhtarian et al., 1995). Estimated net savings from telecommuting were found to be between 153,000 and 205,000 BTU per telecommuting occasion, an equivalent of 0.025 and 0.0342 BOE, assuming an average round trip to work of 36.1 miles used in the studies(Mokhtarian & Henderson, 2000). The associated CO_2 savings are equal to approximately 5.8×10^{-4} metric tons of CO_2 per telecommuting occasion.

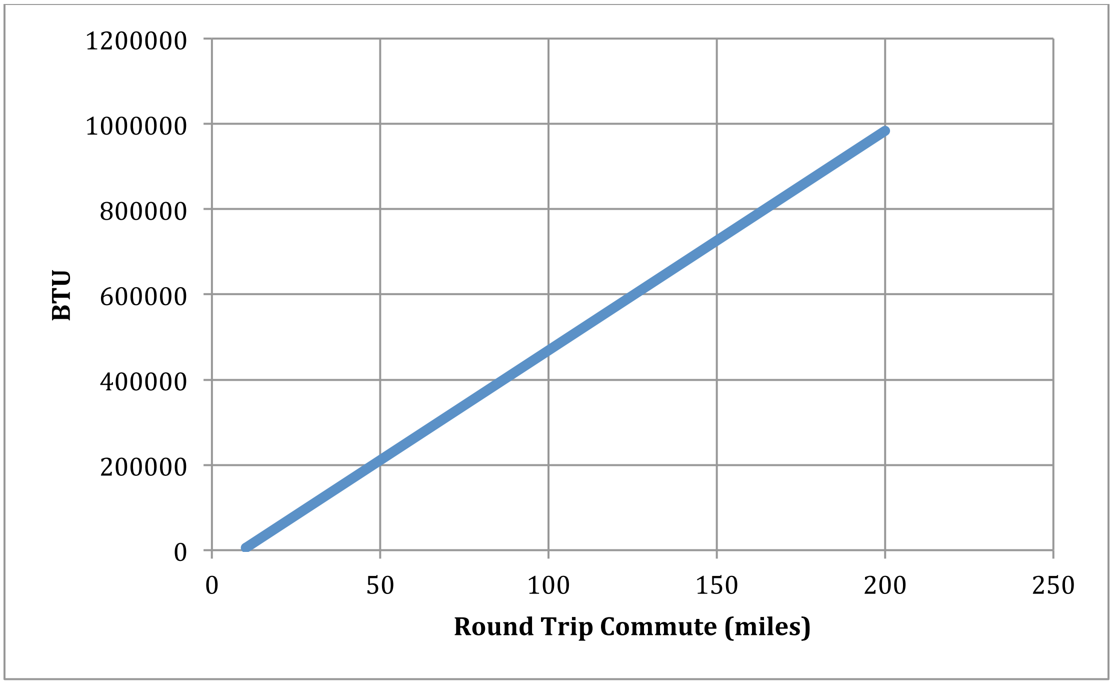

Figure 8.5: Relationship of miles driven for a commute to work and the associated net energy savings in BTU. For round trip commutes less than 10 miles telecommuting expends more energy than it saves due to the average additional heating and cooling used when someone is at home rather than working outside of the house. Adapted from (Mokhtarian et al., 1995).

The estimated energy savings are summarized in Figure 8.5 based on round trip commute distance. If more eligible individuals opted to work from home rather than commuting to an office it is estimated that those telecommuting would reduce daily trips by 51% and reduce travel in personal vehicles by 77% (Fuhr & Pociask, 2011). In the end, converting 14% of US jobs from the traditional commute to telecommuting would decrease the carbon emissions in the United States by approximately 55 million metric tons per year. This accounts for about 1% of the total carbon emissions produced by the United States in a year (Cox, 2009).

8.1.10 Extreme Scenario - Elimination of Personal Transportation

The number one method to reduce and nearly eliminate energy expended in the transportation sector is to eliminate driving and all other modes of transportation that require the use of fuel including public transportation. This energy saving strategy is similar to telecommuting but takes it a step further by omitting the use of vehicles to go anywhere including to stores, school and other activities. To incorporate this energy saving strategy into daily life one may have to walk or bike to locations of interest such as work and grocery shopping, however, as the distance between "home" and places of interest increases the potential for savings also increases. Unfortunately it also makes the complete elimination of personal driving increasingly difficult. This strategy has the ability to completely eliminate the energy an individual expends on personal transportation, unless they participate in activities such as e-commerce which will offset some of the savings to a degree. This means that an individual can expect to reduce their personal energy consumption by approximately 32% and approximately 46.8 million BTU per year or 7.8 BOE per year.

8.1.11 Other Proposals

Outside of the proposals previously discussed there are several additional options that were not covered. For example, an additional way to conserve energy is through the reduction of weight carried in the vehicle. This was not explored in depth because vehicle weight constantly fluctuates with the number of passengers and movement of goods. In addition to the reduction of weight, reducing the use of auxiliary functions, such as media systems in the vehicle will also help to stretch energy further. The actual energy savings from this change depend on the load that each individual function places on the vehicle, however they are typically nominal compared to major functions such as in vehicle air conditioning. One other final way to reduce energy consumption is through increasing the aerodynamics of the vehicle and decreasing the potential drag. The removal of racks and any add on units to hold items such as skis or bikes will help fuel efficiency through the reduction of drag alone. This topic was not explored in greater depth as the variance ranges immensely due to the type of vehicle as well as what type of rack is being used.

8.1.12 Summary

The transportation sector offers many opportunities in order to reduce energy consumption effectively with minimal effort. Although the greatest reduction of energy consumption is the complete abandonment of individual driving, it is not an option that is always practical depending on demographics. Similarly, public transportation is greater than 30 miles away from 13% of the United States population and therefore not accessible by many (Bailey, 2007). The combination of strategies such as carpooling with one other individual coupled with decreased speed and turning off the AC has the capability of saving approximately 0.05 gallons per mile between the two individuals participating in the carpool.

Table 8.5: Summary of the savings an individual can expect per mile by following the suggested proposals with a comparison of the total yearly savings for the average person driving approximately 12,000 miles per year. The Costs of Aggressive Driving assumes that acceleration is decreased from 5 mph/s to 1 mph/s and Reducing Speed assumes that speed is reduced from 75 mph to 50 mph. Telecommuting is only economical if one lives more than 5 miles from their place of work. The savings from Idling are on a per hour basis as opposed to a per mile basis.

Proposal	Gallons Saved per Mile	Gallons Saved per Year
7.1.1 Maintaining Healthy Tires	0.00015	1.7
7.1.2 Elimination of Unnecessary Idling	0.57 gallons/hour	55.8
7.1.3 Turning off In-vehicle Air Conditioning	0.0086	97.18
7.1.4 The Costs of Aggressive Driving	0.0061	68.9
7.1.5 Reducing Speed	0.0043	48.6
7.1.6 E-commerce	0	0
7.1.7 Public Transportation	0.01	113
7.1.8 Carpooling	0.026	293.8
7.1.9 Telecommuting	0.045	508.5
7.1.10 Elimination of Transportation Using Primary Sources of Energy	0.049	553.7

The potential for energy savings that are summarized in Table 8.5 vary depending on the demographics of the individual. Therefore there are specifics to consider when trying to determine the best energy saving strategies for individual use. For those who live in an urban or suburban area where everything is within 10 miles of home it is best to consider eliminating driving completely or switching to public transportation. If riding a bike, walking or public transportation is not viable in a particular urban or suburban setting, then the next strategy to seriously consider is carpooling with someone who lives close by with a similar commute. The savings are further enhanced by practicing the suggested driving practices, such as maintaining healthy tires, using the air conditioner sparingly, as well as reducing speed and acceleration. Similarly the practice of carpooling and driving according to energy-saving techniques is one of the best options for individuals who live in rural areas far away from public transportation, however, it is surpassed by the option of telecommuting, assuming telecommuting is a viable option. Finally, for those who must commute long distances, cannot location another individual heading in the same direction, and is unable to switch to telecommuting, the best technique to make an impact is to practice the remaining energy-saving strategies. This option is possible for nearly everyone with a personal vehicle to follow and cut down on their personal energy consumption and waste production.

8.2 Food Industry

Food is the one of the most important aspects of anyone's life, as it is directly related to our personal health. Many people may not realize how their eating habits affect personal energy usage. Energy used in food production and preparation accounts for more than 25% of the residential energy usage in the United States. This energy is used in the growing and raising of plants and animals for human consumption, the shipping of food raw materials for processing, and the final preparation of the food. Energy in the food sector is used primarily in four areas: personal food preparation at home, food prepared by restaurants, processed food, and the production of animal products for food. A focused effort in each of these four areas to reduce personal energy consumption would make a significant impact on the amount of energy used in the production and preparation of food.

Food preparation at home is where most of the food-related energy is used (Canning). When most people cook at home, they may not cook with energy savings in mind. Given a specific cooking method, there may be alternative cooking methods that can get the same cooking task done with much less energy waste. Some may consume food that was prepared outside their personal homes; food eaten in restaurants, or heavily processed food that requires little to no in-home cooking accounts for another significant fraction of the energy used in the food system.

Regardless of how an individual prepares food or where the food comes from, his or her dietary habits may not be as energy efficient as he or she may realize. Meat and other animal products produced as food require a great deal of energy to raise, and are responsible for much of the energy used in the food system. A simple change in the food one consumes could reduce the food industry's energy use.

The average American who is actively seeking to reduce the amount of energy he or she uses for his or her personal food consumption may not wish to make a serious life-altering commitment, whether that would be becoming a vegan, eating just raw food, or boycotting the supermarket. Anyone can still make a significant reduction in energy consumption by making small changes in each category. With a great deal of varied options, a hybrid approach is reasonable, and the details will be explored. There are benefits to reducing energy consumption that are not so obvious. Using kitchen appliances less will save money on power bills. Changing diet with energy savings in mind, however, has benefits beyond that of just using less energy. The following section analyzes the various ways to save energy as it relates to food consumption.

8.2.1 Household Operations

Household operations, the activities done in the kitchen that use energy, encompasses the widest array of activities that use energy related to individual food consumption. An individual's energy usage in the kitchen boils down to energy used by cooking appliances, refrigerators, and heating water for use in dishwashing (Hager & Morawicki, 2013). Household operations account for 27% of per-capita food-related energy usage, about 12,639,184 BTU per capita (Canning, 2010). Significant impacts can be made in the kitchen by purchasing more energy-efficient appliances, such as refrigerators that use less power and induction stoves, but the investment is rather significant for some and may require years of saving and planning; the topic of purchasing new energy-efficient kitchen equipment is beyond the scope of this report (Hager & Morawicki, 2013). Even without purchasing a whole new kitchen, an individual can reduce the energy used for cooking by being smarter about how existing appliances are used.

Over a fifth of energy for household operations is used for cooking and the absolute amount of energy can be reduced by focused use of cooking appliances (Hager & Morawicki, 2013). Boiling water is a good example of a common cooking method that requires significant energy, and has many opportunities for energy savings. The energy required to take m grams of water, with heat capacity $\mathrm{C_p}$ and heat of vaporization $\Delta\mathrm{H_{vap}}$, from room temperature to its boiling point, $\mathrm{T_r}$ to $\mathrm{T_b}$, and to boil off a fraction, ε, of that water, is given by the following equation:

Equation 8.1
$$\mathrm{E} = \left(\int_{\mathrm{T_r}}^{\mathrm{T_b}} C_p \,\mathrm{dT} + \Delta\mathrm{H_{vap}} * \varepsilon\right) * \mathrm{m}$$

The quantity E can be reduced by either not boiling the water (letting $\varepsilon \rightarrow 0$) or significantly reducing the mass of water that needs to be boiled, relative to a certain quantity of food being cooked. Maintaining a less-than-boiling cooking temperature is equivalent to simmering food at around 194 degrees Fahrenheit. Significantly reducing the mass of water, relative to the mass of the food, is equivalent of steaming. The quantity E, as defined above, is just the energy required to bring a certain quantity of water to a boil (and then let it boil for some time). In reality, the water will lose heat to its surroundings via conduction through the sides of the pan, and subsequent convection from the sides of the pan to the surrounding air, and through convection at the interface of the water with the air above it. The heat lost in the latter manner is the most significant contributor, and can easily be reduced by using a lid on the vessel used for boiling. A calculated 50-85% reduction of heat was lost when simmering with a lid, compared to simmering without one (Brundrett & Poultney, 1979).

As a simple example of simmering instead of boiling, if we assume the heat capacity of liquid water is constant at $4.184\,\frac{\mathrm{J}}{\mathrm{g*K}}$ and the heat of vaporization at normal atmospheric pressure is $2256.4\,\frac{\mathrm{J}}{\mathrm{g}}$, the amount of energy saved by keeping a pot of two liters of water at $194^{\circ}\mathrm{F}$ rather than boiling it is equal to the following:

Equation 8.2
$$\Delta E_{saved} = \left(\int_{363\ K}^{373\ K} 4.184\ dT + \Delta H_{vap} * \varepsilon\right) * m$$

$$= (41.84 + 2256.4*\varepsilon)*2000$$

Where the mass of the water is 4.4 pounds and ε is the mass fraction of the water that has been boiled off during the cooking process. Considering the energy required to heat the cooking water from 194 degrees Fahrenheit to its boiling point at 212 degrees Fahrenheit, at least 79.313 BTU of energy will be saved by not boiling the water. Water has a large heat of vaporization, and by maintaining a non-boiling, but still hot cooking temperature, the extra energy required to boil the water can be saved, and the heat requirements during cooking are only those associated with replacing any heat lost through the interface of the liquid water with the air; the energy required to replace heat lost in boiling depends on how the stove used for the boiling generates heat, and is present regardless of whether or not the water is boiling.

Steaming is another popular and easy alternative to boiling water for cooking. Steaming involves boiling a small amount of water while keeping the food separated from the water. The hot steam evolving from the boiling water cooks the food. Supposing a given amount of food could be steamed with a quarter of the water it would require to cook by boiling, for example using around two cups rather than eight cups, the energy saved is equal to the following (assuming the same quantity of water is boiled off during each method):

Equation 8.3
$$\Delta E_{saved} = (\Delta m \int_{298\ K}^{373\ K} 4.184\, dT) = 313.8*(2000\text{-}500) = 446.14\ \mathrm{BTU}$$

Under the supposition that 25 % of the water is required to steam food compared to boiling, and assuming equal amounts of water are boiled off under either cooking method, 446.14 BTU of energy can be saved when preferring steamed food. This is a reasonable assumption, as a given quantity of food will require a set amount of water to be submerged, whereas steaming that food does not require submersion. Also, a given quantity of food requires a fixed amount of energy from the cooking appliance to cook, and that energy goes directly to boiling the water. There is more heat being generated by the stove because of any heat loss; the heat loss can be significantly reduced in the case of boiling or steaming by the use of a lid on the cooking vessel. An estimated 9 to 56% reduction in the amount of energy is required to cook an equivalent amount of food by steaming, compared to cooking by boiling, and using a pan lid to contain hot steam will result in the larger energy reduction (Hager & Morawicki, 2013). If an individual household averages one meal cooked by boiling water per day, by simmering at 194 degrees Fahrenheit or by steaming the otherwise boiled food, the household can save about 28,949 BTU per year or 162,841 BTU per year, respectively.

A common cooking habit involves using the cooking appliance right up until the point the cooking is done, and turning it off once the food is done. The residual heat left in the appliance is then wasted. Using a technique called “passive cooking”, the heat source is turned off prior to the food being finished cooking; the residual heat goes towards completing the cooking, and much less of it is wasted. A 17 to 23% reduction in the energy required to cook food to completion using the passive cooking method, compared to using a cooking appliance up to the point of the completion of cooking (Carlsson-Kanyama & Boström-Carlsson, 2001). With this method the heat being lost through conduction of the walls of the cooking vessel isn’t being replaced by energy from the stove. The heat left over in the water, in the cooking vessel material, or on the surface of the stove keeps the food at an appropriate cooking temperature. The passive cooking technique can be generalized to other cooking methods, especially cooking in an oven. Other methods for utilizing as much as possible of the energy from cooking appliances are summarized in Table 8.6.

Table 8.6: Table summarizing cooking technique with the estimated reduction in energy compared with cooking without the proposed method. The percent figure is the percent relative to not doing the action, on a per capita basis, not percent of energy use overall

Technique	% Reduction in Energy	Source
Simmering (90 degrees C) rather than boiling (100 degrees C)	69 to 95 %	(Brundrett & Poultney, 1979)
Steaming rather than boiling	9 to 56 %	(Warthesen, Vickers, Whitney-West, & Wolf, 1984)
"Passive cooking"	17 to 23 %	(Carlsson-Kanyama & Boström-Carlsson, 2001)
Simmering with pot lid, vs. open to air	50 to 85 %	(Brundrett & Poultney, 1979)

There is great potential for an individual to save energy by paying some attention to how food is cooked. Table 8.6 shows that under some circumstances, cutting down half the energy used is a reasonable goal. The average energy savings for eliminating boiling and replacing it with simmering is 82%, and the average for replacing boiling with steaming is 32.5%. In the course of a year, a person may use both techniques, which would save an average of 57.5% of the cooking energy expended in a year. True potential of savings is greater with the use of passive cooking, so 50% is a reasonable goal for the dedicated home chef.

8.2.2 Food Sources

The energy associated with the food system not only comes from the energy used directly at home to store and cook food, but also from the production and consumption of different kinds of food. As seen in Figure 7.10, the largest areas that use energy in the food industry that are not directly controlled by the consumer are: processed food, food away from home, and animal products. In 2002, 26.8% of food energy usage was used for processed food, or food that was served in restaurants and cafeteria like establishments (Canning, 2010). The common thread linking these two categories is that the preparation and production of the food is not completed by the consumer.

The energy associated with the processing of food goes above and beyond that of simply producing whole food for cooking at home. Food processing takes the "raw material" food, such as raw vegetables, grains, or meats, and through use of energy and other ingredients, increases shelf life, attractiveness, and convenience of the food. Individuals are better off buying or growing raw materials themselves and cooking them with the energy-saving techniques presented in the previous section. If one completely eliminated processed foods from one's diet, it would reduce one's personal contributions to the energy waste in the food industry by 9.3% (Canning, 2010). Processed foods includes processed dairy products, processed frozen fruits and vegetables, snack foods, and canned foods. People pay for convenience, and that convenience often comes with a cost that is not only monetary, but also represents a significant energy cost.

The other 17.4% of the energy cost associated with restaurant and processed food comes from the extra energy cost associated with eating out of the home at places such as restaurants, cafeterias, and other places (Canning, 2010). The all-day energy requirements of a restaurant results in a great deal of waste. While restaurants may be able to cook large amounts of food more efficiently than individuals at home, the individual patrons of the restaurants have no control over how the food is prepared. Unless a restaurant is specifically dedicated to employing energy-saving practices in the kitchen, a great deal of waste will be an inevitable result of the demands of any restaurant kitchen. A 2010 USDA ERS report evaluating the increase in per capita food energy expenditure states:

> about half of the growth in food-related energy use between 1997 and 2002 is explained by…high labor costs in the food services [sic] and food processing industries, [which] combined with household outsourcing of manual food preparation and cleanup efforts through increased consumption of prepared foods and more eating out, appear to be driving this result.

While the energy consumption by the restaurant industry accounted for no more than 17.4% of the total per capita energy use in the country between 1997 and 2002, its increase during that time was nearly as large as the increase from all other sectors of the food industry, such as processing and production, combined (Canning, 2010),.

The waste incurred by the restaurant industry results from the daily demand on appliances and materials. Restaurants need to continuously cook for a large number of people and the demand on cooking appliances greatly exceeds that of a household kitchen per unit mass of food (T. W.

Jones, 2004). The demand placed on restaurants also results in a great deal of wasted food when compared with households. The average household throws away approximately 467.2 pounds of food per year; restaurants, on average, throw away more than 54,000 pounds of food per year (T. W. Jones, 2004). This calculation is based on the total food waste generated by restaurants reported in Jones's 2005 study. Approximately 54 billions pounds of food is disposed of each year by restaurants in the United States. The individual restaurant goer may be able to help restaurants cut down on the amount of food wasted by taking home any unfinished food, including complimentary items, such as bread.

A significant reduction in the amount of processed or restaurant food one consumes will make a rather large impact in any individual's personal energy contribution. It is unreasonable to expect anyone to cut out processed foods and restaurant food completely, as convenience is much sought-after in today's world. Still, one should be able to save at least 10% of the energy one would otherwise be contributing to the overall food-related energy usage. The 10% reduction goal would require only a 38% reduction in consumption of the amount of processed food and food away from home. Around 26% of the overall food energy is used in the restaurant and processed food sector, so this reduction of reliance on restaurant and processed food will reduce the average energy demand on those food sources by approximately 10% of the total food energy use . In the end, 10% percent of the total energy consumed in the food industry is around 4.68 million BTU, or 0.808 BOE per person.

8.2.3 Dietary Practices

The energy in our food comes indirectly from the sun. The plants on earth use the sun's radiated energy to create energy-rich molecules, such as glucose, but they are unable to make use of all of the energy the sun has to offer. As animals eat those plants, they are extracting the energy that the plants have stored from the sun, but again they are unable to extract all of that energy. A great deal of energy is wasted as it moves down the food web; because of this inefficiency, it should be expected that animal-based food products require a much greater energy input than their plant-based counterparts. Indeed, the livestock used to produce all of the most common animal-based foods requires a much greater investment in terms of water resources, land resources, and energy resources (Pimentel & Pimentel, 2003). The most common animals we use to produce our food are cattle, chickens, turkeys, sheep, and pigs.

Table 8.7: Summary of the energy ratio for the most commonly used livestock in the food industry based upon the energy used to raise the animal (Pimentel & Pimentel, 2003).

Livestock/Animal Product	Energy Ratio
Lamb	57:1
Cattle for beef	40:1
Cattle for dairy	14:1
Chicken for Eggs	39:1
Chicken for Meat	4:1
Pigs	14:1
Turkey	10:1

Table 8.7 shows the ratio of energy used to raise the animal to the energy equivalent in BTU of protein in the food product. For example, for every 57 BTU spent to raise a lamb, the meat from the lamb will supply one BTU, or 0.25 Calories.

Pimentel et. al. concluded in their 2003 analysis of the energy resources required for various diets that "the [American] meat-based diet requires more energy, land, and water resources than the lactoovovegetarian diet." A lactoovovegetarian is a person who chooses to omit all meat from his or her diet, but still consume eggs and dairy products. Some vegetarians exclude eggs and dairy products; although the term "vegan" is often associated with such a diet scheme, a true vegan does not use any animal based-products in his or her lifestyle. A vegan's dedication to rejecting animal-based products extends to all aspects of his or her life. If a person became a dietary vegan, or a vegetarian, he or she would be eliminating a source of energy use that accounted for approximately 18.1% of the energy consumption in the 2002 food industry (Canning, 2010).

In 2011, The United States Humane Society ran a "meatless Mondays" campaign, during which they produced a short video that cited an EDF (Environmental Defense Fund) study. The EDF study claimed that if everyone in America replaced all the chicken with vegetables in one meal per week, it would reduce the carbon emissions required for chicken production equivalent to taking 500,000 cars off the road. The Humane Society is implying that the approach of cutting out all the meat in an individual's diet for a single day of the week will make a significant impact on the reduction of energy usage and waste production.. If we assume that the average omnivorous American does not alter his or her meat consumption from day-to-day during the week, but cutting out one seventh of the meat an individual eats during the year will make only about a 2.7% change in the national contribution to food energy usage (Canning, 2010). To cause a 10% or greater reduction, one would have to not eat meat at least four days a week which would save 8.47 million BTU, or 1.46 BOE per person per year. The energy used in the meat industry accounts for 18% of the 47 million BTU consumed per person by food-related energy costs. If an avid meat eater decided to eat less than half the meat he or she currently eats, he or she could make a large dent in his or her personal energy contribution.

8.2.4 Extreme Scenario - Raw Food Only

If an individual wished to make the largest energy impact possible by changing how he or she obtained and prepared food, the most extreme scenario would entail completely eliminating animal products from his or her diet and consuming all food in a fresh, raw form. The extreme case would eliminate all need for cooking and refrigeration, and would eliminate all the energy in the "household operations" category of food-related energy expenditure. Eliminating animal products and the need for cooking and refrigerating food means a 45% reduction in the energy a person contributes to the annual food energy usage by the United States, an astounding 21.07 million BTU, or 3.64 BOE per person. A more extreme measure would also eliminate all restaurant and processed food, which would save an additional 12.17 million BTU, or 2.1 BOE per person. If these two measures were taken simultaneously, an average person living in the United States could reduce his or her personal contribution to the energy used in the food industry by 5.74 barrels of oil.

8.2.5 Other Ideas

There are additional proposals that one could follow to potentially save energy, but could not be evaluated further due to lack of available data or presented a relatively small potential for energy savings. In the household operations sector, energy can be saved by using a solar cooker whenever possible. Energy from the sun, rather than energy from burning fuels for electricity, would be used to cook food. It could say up to the same amount of energy used by regular appliances but is limited by the presence of sunlight which varies day to day and region to region. Also, similar to using a lid at all times, using a cooking vessel on a stove with a larger diameter than the stove heat source will cover all the area of the stove open to heat transfer, and much less of the stove's heat is wasted (Hager & Morawicki, 2013). Researchers have investigated the effect of cooking large quantities of food, and how the cooking energy-to-food mass ratio decreases with an increasing mass of food, so that one can cook a given quantity of food with much less energy per unit mass of food (Newborough & Probert, 1987) (Oberascher, Stamminger, & Pakula, 2011) (Carlsson-Kanyama & Boström-Carlsson, 2001).

Within the food industry, some people claim there are advantages to obtaining produce as close to the source as possible. It is usually fresher and of higher quality than the produce found at the local supermarket. The closest an individual could come to obtaining produce directly from the source is growing the produce oneself. A significant land and time investment is necessary to eat exclusively self-grown foods, so keeping a small vegetable or herb garden is a reasonable alternative. A personal garden is a small capital investment that will eliminate the need for the supermarket to supply the vegetables and herbs in said garden; furthermore, personal gardens can be fed by composting organic waste produced by the household. Energy in food is wasted whenever uneaten food is thrown out. Food waste can be saved and composted, and the compost may be added to a personal garden to recycle the energy contained in the food waste. If the upkeep of a personal garden is unrealistic, many who are seeking fresher produce can buy "local" produce, food directly from farms that are within a reasonable driving distance. Currently there is limited data to suggest that a local food distribution system results in overall energy savings.

8.2.6 Summary

The food industry represents a significant area of wasted energy and inefficiency; therefore there is a great deal of room for energy savings. An average individual living in the United States can focus energy-saving efforts in three major areas to optimize the effectiveness of those efforts: energy used during personal cooking at home, energy used by food source, and energy associated with animal products in diet. The energy used during personal in-home cooking can be greatly reduced by smart use of cooking appliances to save at least 1.28 million BTU, or 0.221 BOE per person per year. High demand for restaurant and processed food creates a disproportionately large amount of energy consumption and waste production for those sectors. A reasonable two-fifths reduction in the amount of restaurant and processed food eaten would result in a lower demand for food from those sources and could reduce their need for energy by at least 4.68 million BTU, or 0.808 BOE per person per year. In addition, animal products are inherently more energy-intensive to produce than plant products, and a reduction of dietary animal products can lessen the energy demand on the food industry to produce meat, eggs, dairy, and other products. A reasonable four-sevenths reduction in the amount of animal products consumed would result in a lower demand for animal products, and could reduce their need for energy by at least 8.47 million BTU, or 1.46 BOE per person per year.

Many people may not be able to follow all of the suggestions made to reduce their personal contribution to the energy used in the food industry, but they can decide what is best for them given their own personal situation. For example, someone who has the time to routinely cook for themselves at home does not need to rely on restaurant or processed food to eat. The home cook may focus efforts on utilizing energy-saving cooking techniques discussed as “household operations." Time can be set aside each week for careful meal planning, grocery shopping and cooking. Despite the method used to obtain food, anyone can make an effort to reduce the amount of animal products in his or her diet. The main obstacle for most people is personal habits; most people are brought up eating meat almost daily, and may not like plant-based alternatives such as grains, legumes, and vegetable. There may be an initial effort and a need for self-control in the beginning of a reduced-meat diet plan, but it is an easy change to make compared to the other two suggestions. In the beginning, significant meal-planning might be necessary to adequately replace meat in most meals, but with time and dedication, anyone can reduce their meat consumption to benefit of energy use in the food industry.

The lifestyle of the average person is not overwhelmingly in favor of the perpetually busy or the stay-at-home chef, so a hybrid approach to the above suggestions is suggested for most people. Anyone who does any regular cooking at home has the opportunity to employ energy-saving techniques in the kitchen. Anyone who eats processed food or restaurant food has the opportunity to replace two out of every five of those meals with a fresh home-cooked meal. Anyone who already eats meat can make efforts to reduce their intake of meat, or choose meats that are less energy-intensive to produce. Since the average person falls into all three categories, they can make efforts in all three areas. For some who already live by these suggestions, the associated changes may have a small impact on their personal energy contribution; for others, these may be big changes to make and their personal energy reduction will make a large impact on the energy consumed overall. With planning, anyone can significantly cut their personal contribution to the energy used in food production and preparation.

8.3 *Climate Control*

Climate control, the use of heating and air conditioning to control the temperature of one's home, is the final of the three primary contributors to the national overall energy consumption in the residential sector. Residential climate control plays a key role in the comfort level inside of a person's house. The easiest way to save energy is through not using air conditioners in the summer and using the minimum amount of heating possible to survive the winter. As one may expect, the main obstacle for these strategies is the individual's desire to be comfortable and set the home thermostat to reflect this desire. The main goal of the proposals found within this section are to limit discomfort while maximizing the energy savings and the reduction of waste production. Without looking at spending habits, the major way to save energy with regards to climate control is through thermostat adjustment strategies. Thermostat adjustment strategies are generally easy to implement and can make noticeable changes in energy consumption. There is also the potential for smaller strategies within climate control energy savings, such as closing the blinds or using fans.

8.3.1 Dynamic Thermostat Changes

One of the primary ways to save energy in the climate control sector is through the use of programmable thermostats to implement the idea of "setback temperatures" in the cooler times of the year and "set-up temperatures" in the warmer times of the year. The general idea of a set-up or setback temperature is to use the thermostat to bring the temperature of the residence closer to that of the outside environment. This idea uses programmable thermostats to change the temperatures during different times of the day based on a preset schedule; for example: when the individual is at work, at school, or sleeping. During these times, the individual will not notice the change in temperature and therefore energy is conserved without significantly altering an individual's level of comfort. In addition, less energy is lost through windows and doors when the temperature difference between the inside and outside environments is smaller. The impact of this energy saving strategy varies with the region due to the change in external temperatures and required heating or cooling loads.

The energy requirements of warmer climates, such as Florida and California, differ from colder climates, such as Michigan; this must be taken into account when providing recommendations for individuals to save energy. An experiment was run on a house system in Miami, Florida, which is used as a representative case for dynamic thermostat strategies and their potential energy saving in the warmer climates. The baseline for this experiment was 72 degrees Fahrenheit for heating and 78 degrees Fahrenheit for cooling (Moon & Han, 2011). Three different strategies were tested to find the experimental data points. The first was a baseline where there was no set temperature variation throughout the day. The second was a nighttime set temperature experiment where the temperature was brought closer to that of the outside environment, for approximately 8 hours of temperature change when the residents were sleeping. The third and final experiment included lowering the indoor temperature both at night, and during the typical workday, leading to a total dynamic change of 15 hours. The setback temperature used for cooling was 60 degrees Fahrenheit and the set-up temperature used for the heating was 82 degrees Fahrenheit (Moon & Han, 2011). In Miami, the overall baseline energy usage per household per year was approximately 38.2 million BTU or 6.4 BOE combined from heating and cooling. As the average household size is approximately 2.61 people, approximately 14.63 million BTU or 2.44 BOE are consumed per person. The overall percentage of energy savings, when considering both heating and cooling, is approximately 12.5% for participation in nighttime setbacks alone and 17.4% for the combination of day and night setbacks (Moon & Han, 2011).

In order to study the energy saving potential in a colder climate compared to the relatively warm Florida, the city of Detroit, Michigan was identified as the next site for a housing system to test dynamic thermostat strategies. The same baseline, setback temperatures, and setup temperatures used in Miami were used in Detroit. As one would expect with a cooler climate, the most notable difference was a shift from energy being used mostly for cooling to energy being used mostly for heating. The total annual energy usage for both heating and cooling combined in Detroit for the baseline set-up was approximately 34.21 million BTU per person or 5.7 BOE per person (Moon & Han, 2011). When employing dynamic thermostat changes for both heating and cooling the overall energy savings are approximately 6 million BTU or 1 BOE for nighttime setbacks alone and 9.14 million BTU or 1.52 BOE for both day and night setbacks (Moon & Han, 2011).

Table 8.8: Comparison of energy usage and savings, in both BTU and BOE per person per year, for baseline and dynamic temperature change strategies for Miami, Florida and Detroit, Michigan. Adapted from (Moon & Han, 2011).

City	Strategy	Total Energy (per person per year)	BOE(per person per year)	Energy Saved (per person per year)	BOE Saved (per person per year)
Miami, Florida	Baseline	14.63 million BTU	2.44 BOE	N/A	N/A
	Nighttime Setback	12.80 million BTU	2.13 BOE	1.83 million BTU	0.31 BOE
	Night and Daytime Setback	12.08 million BTU	2.01 BOE	2.55 million BTU	0.43 BOE
Detroit, Michigan	Baseline	34.21 million BTU	5.70 BOE	N/A	N/A
	Nighttime Setback	28.20 million BTU	4.70 BOE	6.01 million BTU	1.00 BOE
	Night and Daytime Setback	25.07 million BTU	4.18 BOE	9.14 million BTU	1.52 BOE

As summarized in Table 8.8, the overall energy consumption in the warmer climate of Miami is less than the energy consumption in the colder climate of Detroit. As more energy is consumed it follows that there is the potential for greater energy savings in colder climates. The highest possible energy savings in Miami are around 17.4% whereas in Detroit the highest energy savings are a much higher 26.7%. This illustrates that colder climates can save a much higher percentage of energy, by implementing the same strategies. This relation shows that heating energy is most likely easier to save and a much more efficient area to cut back energy usage in.

The analysis of environments such as Miami and Detroit does not fully capture the main focus area of this report. This report is focused mostly on the northeastern United States. The northeastern United States does not have an environment that can be accurately represented by either of the two locations in the previous study. To achieve a better idea of the potential energy saving in the northeastern United States data was extrapolated from studies completed by

Manning 2007 in Canada. The climate is comparable to that of the northeastern United States with summer temperatures between 41 and 95 degrees Fahrenheit and winter temperatures between -17 and 59 degrees Fahrenheit. A major assumption to note is that the residence studied was in complete compliance with Canadian energy efficiency standards (Manning et al., 2007). This means that greater energy savings are possible to achieve in homes that are not as energy efficient. The experimental residence in Canada also only had a single benchmark temperature of 72 Fahrenheit as well as had a shorter setback period of seven hours when compared to the previous articles.

Dynamic temperature changes in heating and cooling allow for sizeable savings in the cooler climate of the northeastern United States. The overall energy consumption, from the experiment in the previous paragraph, for heating and cooling is approximately 31.11 million BTU per person per year or a BOE value of 5.19. This baseline energy consumption is composed of the 27.05 million BTU or 4.51 BOE for heating in the winter and 4.06 million BTU or 0.68 BOE used in the summer (Manning et al., 2007). Looking first at the summer setback, there is a total energy savings of approximately 0.45 million BTU or 0.075 BOE. The winter nighttime and daytime strategy with a setback temperature of 61 degrees Fahrenheit has the largest savings in the winter, approximately 3.3 million BTU or 0.55 BOE (Manning et al., 2007). The summer set-up and winter setback strategies are combined for each of the three winter strategies, nighttime setback, day and night setback to 64 degrees, and day and night setback to 71 degrees. These different combinations are represented in Table 7.9 below.

Table 8.9: Energy usage and savings, in both BTU and BOE per person per year for the different dynamic temperature change strategies compared to the baseline. This data would be representative of the northeastern U.S. (adapted from (Manning et al., 2007))

Strategy	Total Energy (per person per year)	BOE (per person per year)	Energy Saved (per person per year)	BOE Saved (per person per year)
Baseline	31.11 million BTU	5.19 BOE	N/A	N/A
Winter Night (64°F) with Summer Day (77°F)	29.08 million BTU	4.85 BOE	2.03 million BTU	0.34 BOE
Winter Day and Night (64°F) with Summer Day (77°F)	28.08 million BTU	4.68 BOE	3.03 million BTU	0.51 BOE
Winter Day and Night (61°F) with Summer Day (77°F)	27.35 million BTU	4.56 BOE	3.76 million BTU	0.63 BOE

Significant energy savings are possible even in the energy efficient home that was summarized in Table 8.9. The energy savings in an energy efficient home with this strategy can be as high as approximately 10%. Since energy usage for climate control accounts for approximately 16% of a person's overall energy usage for the year, this 10% savings translates to a 1.6% savings on overall energy. Considering how little effort goes into this strategy and the minimal sacrifice, a savings of 1.6% overall energy per year per person is significant.

Comfort level is an important consideration when trying to save energy related to climate control since changes in thermostat settings are bound to reduce comfort, and that is an additional cost for the energy savings. It is possible for energy to be saved in regards to climate control without the residents being forced to feel uncomfortable. Past studies have modeled the potential energy savings based on "comfort bands." These comfort bands provide upper and lower bounds to designate at what point the average person will experience too much discomfort. The "comfort bands" vary upon the room and are calculated using the idea that within the bounds at most 10% of people will experience thermal dissatisfaction (Molina et al., 2011). The Institute of Electrical and Electronic Engineers designed an experiment to analyze energy savings on climate control while remaining within these "comfort bands." It was found that savings of approximately 20% can be obtained while remaining within the "comfort bands" (Molina et al., 2011). Figure 8.6 below illustrates the discomfort experienced by an individual in both the base case and the optimized case. The discomfort is represented in terms of accumulation which is essentially the sum of the level of discomfort every 10 minutes. Despite the large accumulation of discomfort experienced over the course of the year illustrated in the figure there was no period of time where more than 10% of people would be thermally dissatisfied with the temperature (Molina et al., 2011).

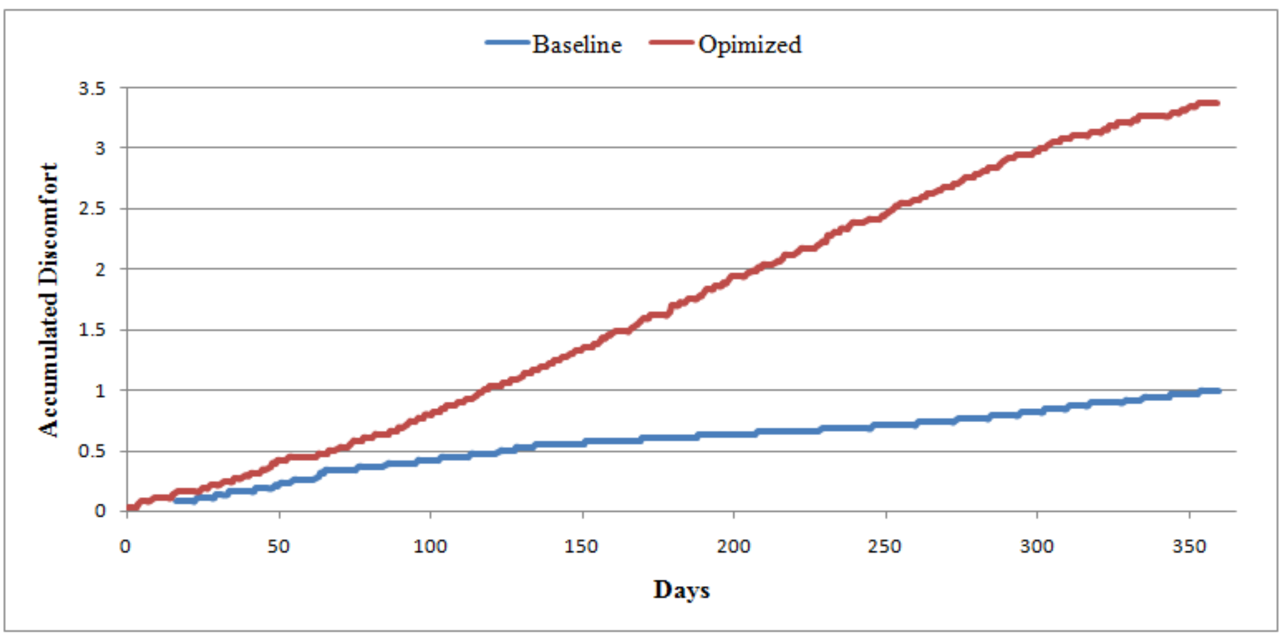

Figure 8.6: Accumulated discomfort, the sum of discomfort experienced every ten minutes, of residents for both the baseline case and the computer optimized case scaled to 1 being a full year of base case for a constant energy cost situation. Adapted from (Molina et al., 2011).

Overall, the idea of heating and cooling set temperature manipulation can make a fairly large difference in energy usage for climate control while keeping the comfort level within the acceptable limits for approximately 90% of the population. This shows that comfort level is not a large limiting factor for energy savings, as even with this optimized situation from the IEEE article, discomfort on a day-to-day basis is limited within acceptable regions yet still has the potential of reducing energy consumption by 20% (Molina et al., 2011).

8.3.2: Static Thermostat Changes

The use of a full-time setback strategy is another major way to impact climate control energy usage in a residence, without purchasing newer and more energy efficient appliances. It is a simple and effective strategy centered around heating and cooling the residence less all day instead of only during times when residents are least likely to feel the impact. This strategy does have the negative effect of decreasing comfort level more than the previous time based strategy, however the energy savings are much greater for the same thermostat temperature change. This negative aspect is potentially a non-negotiable issue as everyone sets their thermostats for exactly the desirable temperature for comfort.

It is suspected that most people overset thermostats based on the relation between the temperature of a room and the distance of that room from the thermostat. Thermostats are typically centrally located in a residence on the main floor. This implies that the far ends and the other floors in the residence are going to be at different temperatures than the area nearest the thermostat. Since the thermostat is typically not in an area where it is exposed to windows or other external temperature variations, it will reach the set temperature before the other rooms will and thus has to be “overset” to get the desired outcome throughout the house (Meyers, Williams, & Matthews, 2010). This results in a variation in temperature throughout the house and the variation can range from 4.6 to 8.1 degrees Fahrenheit from room to room (Meyers et al., 2010). This means the temperature set on the thermostat may not be the actual temperature of every room in the house due to the thermostat's inability to sample temperatures distant from its location.

The amount of energy saved by not oversetting the thermostat, or simply reducing the difference between external and internal environment temperatures by a small amount can be significant. It is estimated that the average person oversets their thermostat by up to 5.4 degrees Fahrenheit (Meyers et al., 2010). If an individual adjusts their thermostat by merely 1.8 degrees Fahrenheit modeling can be used to determine how much of a difference the change in temperature will make in energy usage for the overall house expenditure on climate control. This particular change in temperature resulted in approximately 5.4% savings in winter and 9.06% savings in summer for the specific locations in Table 8.10 below. The savings are calculated using a baseline of 70 degrees Fahrenheit in winter and 75 degrees Fahrenheit in summer (Meyers et al., 2010).

Table 8.10: Percent energy savings in both heating and cooling by changing set temperature by 1.8 degrees Fahrenheit in a few select cities around the United States. N/A indicates insufficient data heating or cooling degree days. Adapted from (Meyers et al., 2010).

City	Cooling Savings (set 1.8°F up)	Heating Savings (set 1.8°F down)
Barrow, AK	N/A	5.4 %
Bismarck, ND	N/A	5.4 %
Houston, TX	9.2 %	4.7 %
Miami, FL	9.2 %	4.7 %
San Francisco, CA	N/A	5.4 %
Syracuse, NY	8.5 %	5.4 %
Washington, DC	9 %	5.2 %
Yuma, AZ	9.4 %	4.7 %

The reduction in an individual's overall energy usage can be calculated by multiplying the percent that heating and cooling energy accounts for out of total energy by the savings percentages in Table 8.10. Using this mathematical relationship, the Meyers article states that the 1.8 degrees Fahrenheit setback and set-up can reduce a residence's overall energy usage by 2.25% (Meyers et al., 2010). The energy savings from this strategy translates to approximately 1.5 million BTU or 0.25 BOE per person per year based on the data in the Meyers article. This data was based on the assumption of only 1.8 degrees Fahrenheit oversetting of thermostats when the actual was most likely around 5.4 degrees Fahrenheit. This means that setting the thermostat normally, but carefully as not to overset, would increase the energy savings to approximately 8% of overall energy which is off by 5-6% of the overall energy for the 5.4 degree overset assumption (Meyers et al., 2010).

The United States Environmental Protection Agency provides an energy savings calculator to estimate the energy savings both with and without making use of changes in set temperatures. This calculator allowed for a quick and easy comparison between these set temperature strategies as well as between different locations around the United States. The calculator will be set for a baseline where the heating and cooling temperature are both 72 degrees Fahrenheit. The data from this savings calculator are displayed below for a few select cities. The time-based strategy is assumes a 7-hour nighttime change and a 7-hour daytime change, which leaves 10 hours of unchanged heating and cooling. The results of these calculations, in Table 8.11 below, show the amount of energy which can be saved when using this strategy instead of the dynamic thermostat strategy.

Table 8.11: Heating and Cooling Energy Comparison of the Two Proposals at two different set temperature changes in the form of raw energy usage (BTU and BOE) per person per year. The baseline is a constant 72°F in the house while the proposed strategies follow the temperature change listed next to tem. This change is a rise in residence temperature in summer and drop in winter. The two strategies are dynamic, 14 hours of changer per day, and static, 24 hours of change per day. Data calculated using the EPA calculator tool from (U.S. EPA, 2004)

City	Baseline (72 F)	Dynamic (2 F change)	Static (2 F change)	Dynamic (4 F change)	Static (4 F change)
Worcester, MA	36.97 Million BTU (6.16 BOE)	35.75 Million BTU (5.96 BOE)	34.98 Million BTU (5.83 BOE)	34.18 Million BTU (5.70 BOE)	32.99 Million BTU (5.50 BOE)
Boston, MA	30.57 Million BTU (5.10 BOE)	29.73 Million BTU (4.96 BOE)	29.27 Million BTU (4.88 BOE)	28.47 Million BTU (4.74 BOE)	27.59 Million BTU (4.60 BOE)
Los Angeles, CA	9.69 Million BTU (1.62 BOE)	9.46 Million BTU (1.58 BOE)	8.97 Million BTU (1.49 BOE)	8.89 Million BTU (1.48 BOE)	8.24 Million BTU (1.37 BOE)
Houston ,TX	15.36 Million BTU (2.56 BOE)	14.56 Million BTU (2.43 BOE)	14.29 Million BTU (2.38 BOE)	13.79 Million BTU (2.30 BOE)	13.18 Million BTU (2.20 BOE)
Salt Lake City, UT	32.49 Million BTU (5.42 BOE)	31.57 Million BTU (5.26 BOE)	30.69 Million BTU (5.11 BOE)	30.27 Million BTU (5.04 BOE)	28.54 Million BTU (4.76 BOE)

When compared to the time based proposal, the energy savings from the 24 hour proposal are much greater when using the same set temperature. This makes sense since the time based proposal is essentially doing the same thing as the 24 hour proposal except during a smaller portion of the day. The amount of energy saved is higher, but so is the overall accumulated discomfort. The individual must take into account their preferences for a more comfortable environment and compare these preferences against the benefits of being more energy efficient, including the reduction of the monetary costs associated with heating and cooling systems.

8.3.3: Closing Blinds and Shades on Windows

Closing blinds and shades on windows has a much smaller potential impact on energy savings compared to altering the room temperature, but is simple to implement and requires almost no sacrifice. By closing the blinds during the warm periods of the year heat gains from solar radiation is reduced, and during the colder times less heat is lost through the window glass leading to less energy expended to maintain the room temperature. Reduction of solar gains alleviates some of the extra strain that is put on the residence's cooling system by the increased temperature due to the sun. Limiting the solar heating effect to the area between the blinds and the window can help reduce this increased strain on the cooling system as well as limit convective heat transfer in the gap if the window glass and the shade are within close proximity, typically around half an inch.

There are several factors that impact the effectiveness of energy savings from blinds. The first is the type of blind used. For example, according to one source a roller blind with a certain size gap, 25 mm at the window head, less than 5 mm at the sides of the shade, and no gap at the window sill, between the blind and the window "reduces the heat loss by 30%" (Littler & Randall, 1984). Another method to increase energy savings from blinds is called aluminization which entails covering the blinds with the metal aluminum or aluminum paint. This process increases the reflectivity of the blinds and decreases the absorption of light helping to minimize the solar gain by reflecting the light back out the window. It is estimated that this aluminized blind setup "conserves 45% of the normal heat loss" (Littler & Randall, 1984). This normal heat loss defines the amount of heat energy that is lost through the window to the cooler exterior environment during heating times or the amount of heat energy that seeps into the room from the hotter exterior environment during cooling times.

The energy lost through the window varies depending on the type of window and frame, as well as how much area the window takes up. Different windows will have different values of the heat transfer coefficient, U. Windows that are triple glazed with a low-E coating and insulated vinyl frame have a U value of around 0.18. The less efficient double glazed windows with aluminum frames are at the high end of the U value range with a heat transfer coefficient of 0.63(2007). This calculation uses the general form of the heat loss or heat transfer equation, which follows.

Equation 8.4 $$Q = U*A*\Delta T$$

In this equation, Q is the heat transfer in energy per unit time, U is the heat transfer coefficient in energy per unit time, area, and temperature, A is the area, and T is the temperature. The basic assumption is that the average temperature is 52.5 degrees Fahrenheit which is equivalent to 11.4 degrees Celsius (National Weather Service, 2005). The temperature difference can then be found by subtracting this number from the average temperature inside a house, 72 degrees Fahrenheit or 22.2 degrees Celsius. Then, using the highest value of U and the value of T stated above, the overall energy loss through a window can be found. This energy loss is approximately 203,374 BTU or 0.034 BOE, per square meter of window space per year. This means the 30% energy savings from the Littler book equates to 61012.2 BTU or 0.01 BOE, per square meter of window space per year. The energy savings for the most energy efficient windows becomes 17432.06 BTU or 0.003 BOE per square meter of window space per year. The numbers seem small, however the energy is saved with minimal effort. The only action that has to be performed is to close the blinds, which requires little to no effort or modifications to everyday life.

8.3.4 Extreme Situation – Maximum Set Temperature Change

The maximum potential savings that can be achieved using these strategies comes from an extreme case of their implementation. The EPA calculator can be used to estimate the savings of this extreme case. The most extreme boundaries that the EPA calculator can handle is a heating temperature of 50 degrees Fahrenheit and a cooling temperature of 90 degrees Fahrenheit. The city of Worcester, MA is the representative city used for this extreme situation. The baseline energy usage for Worcester, MA is 36.97 million BTU or 6.16 BOE per person per year. Under the extreme conditions of 50 and 90 degrees Fahrenheit for heating and cooling respectively, the total energy usage for the dynamic temperature strategy is approximately 23.45 million BTU or to 3.91 BOE per person per year. For the static temperature strategy, the energy usage becomes 13.52 million BTU or 2.25 BOE per person per year. The dynamic temperature strategy saves approximately 13.52 million BTU or 2.25 BOE per person per year while the static temperature strategy saves approximately 23.45 million BTU or 3.91 BOE per person per year. The savings for the extreme condition are massive, however this condition is very unlikely to be implemented in an average home. It is for this reason, that the temperature changes for the normal calculations were two and four degrees Fahrenheit shifts as opposed to of the approximately 20 degrees Fahrenheit shift of the extreme case.

8.3.5 Other

When analyzing the potential energy saving techniques that people could use with regards to climate control, various potential options were conceived. The three analyzed proposals are not the only potential techniques for reducing energy consumption. The proposals that were analyzed in depth were chosen due to their ease of implementation, effectiveness, and minimal impact on daily life. There were other potential ideas that could result in energy savings but had a challenge in one of the three main areas of desirability: ease of implementation, effectiveness, and impact on daily life. The challenges include obstacles such as: the strategy is difficult to implement, the strategy is ineffective, or has a significant impact on daily life.

One of the ideas that was conceived, but ultimately not analyzed in depth was the use of a space heater. This idea proposes turning the heat down to the bare minimum to keep the pipes from freezing, while keeping the residents warm with space heaters. This would reduce the energy usage in a home considerably, however this action would most likely result in a much higher accumulation of discomfort or even the potential breaking of the comfort band temperatures. This idea is very hard to perform mathematical analysis on due to the large number of variables such as: temperature, room size, airflow, thermal resistance, etc. As such, the best way to check its effectiveness would be through rigorous experimentation, however these experiments would require large amounts of time and resources.

Another lifestyle change that was a potential candidate for energy savings analysis was the use of fans instead of air conditioning. This idea was ultimately not analyzed in depth due to personal preferences. The cooling effect of fans is not generally based around cooling the room itself, but rather causing forced convection of heat off the surface of a person’s skin. This means that the room itself will get cooler due to airflow, but not by a large amount, and the effects of the fan will be felt mostly while the fan is pointed directly at the person. The effectiveness of a fan based cooling system revolves entirely around the individual and is not easily generalized to a whole population. Fans could be a viable option to save energy while also keeping the individual cool, but is more of a personal experiment. Each individual has to decide if the fan works well enough for them to remain comfortable, as it is difficult to quantify comfort based on evaporative cooling by forced airflow as it is mostly personal opinion.

All of the other major proposals that were considered included large scale purchasing. As the goal of the report centered around lifestyle changes and not purchasing practices the ideas were not considered. These ideas included changing heating resource, buying more efficient appliances, and buying better insulation for the residence. Although extremely effective in saving energy, these strategies are not within the scope of the report.

All of the ideas mentioned in this section may still be worth exploring in the future or on an individual basis. People who feel more strongly about saving energy can go to the extremes and implement strategies such as the space heater method. Individuals would have to be willing to sacrifice their comfort level, and also perform research to see how effective the strategy is and how to best implement it. The possible energy saving techniques that this report avoided analyzing in depth are presented in this section to make it possible for people to explore them based on their own interest or for future research opportunities.

8.3.6 Summary

The data illustrates that both time based and constant temperature changes throughout the house can lead to some fairly large changes in energy usage with regards to climate control. If both of these strategies result in energy savings, how can someone decide which one of these strategies to implement? The energy saving technique that is best to implement will depend on the individual. Once the pros and cons of each proposal are apparent and easily comparable, the individual can decide which set of pros outweighs its respective cons in their life. To make this decision easier, the pros and cons of both of the aforementioned proposals for energy savings in climate control are briefly described below.

The time-based strategy requires more planning to set up and is most easily performed by a programmable thermostat. The programmable thermostat is a purchase and thus adds a small start up cost. This start up cost also accompanies a lesser amount of savings due to the reduced time of temperature change. Despite requiring an initial cost and saving less energy annually than the constant strategy, the time-based strategy does have some positive aspects. The time based strategy is more comfortable for occupants because the temperature changes are implemented either exclusively or almost exclusively during times of the day where the residents are either not home or sleeping. This means that the residents can be more comfortable in their house while they are home and awake, but still save energy while they are away or asleep. This strategy allows a compromise between comfort level and energy savings.

The constant temperature strategy requires no start up cost and can be performed by essentially any thermostat. This strategy will also typically accompany the largest energy savings as shown by the mathematical comparison earlier on in this section. There is a tradeoff present with this strategy, despite the seeming positive nature of it. The comfort level of the residents in the house will be much lower as they will have to experience the temperature changes in their environment instead of only having the set temperature changed while the residents are away or asleep. With all these things considered, the individual must decide whether or not the tradeoff is worthwhile.

The other main proposal was to shut the blinds in the windows of the residence. This strategy is suggested for implementation regardless of which of the other two energy saving strategies is implemented. This strategy will essentially always reduce the amount of energy lost as heat through windows year round or added as heat from solar gains through the windows in the summer. This strategy is easy to implement, saves energy, and has little to no effect on everyday life, as such there is little downside to implementing it.

8.4 Overall Energy Savings

The three major sectors where an individual uses the most energy, and thus can save the most energy, are transportation, food industry, and climate control. These sections have been presented separately so far, however the most effective way to save energy is to combine the practices from all three areas. The combination of these three areas allows for a multitude of possible combinations of strategies that best fit an individual’s lifestyle. An individual may be more likely to take action with respect to one or two of the categories depending on personal preferences. Individuals can mix and match different proposals to find which ones they prefer and are willing to implement. An overview of the three sections is provided below along with Figure 8.7 which shows the potential savings from the combination of both the average and extreme savings for all three areas. The following tables and figure allow for the facilitation of the combination of the different strategies by allowing an individual to quickly discern how much various strategies can save.

Table 8.12: Summary of the average energy saved per year per person for each energy saving proposal in the transportation sector. The calculations assume that an average of 12,000 miles are driven by an individual per year, one gallon of gasoline produces 8.887 x 10^{-3} metric tons of CO_2 and one gallon of gasoline can provide 114000 BTU of energy (U.S. EPA).(S. C. Davis et al.)

Proposal	**Million BTU/year/person**	**Metric Tons CO_2**	**BOE/year/person**
7.1.1 Maintaining Healthy Tires	0.19	0.02	0.03
7.1.2 Elimination of Unnecessary Idling	7.25	0.57	1.21
7.1.3 Turning off In-vehicle Air Conditioning	11.08	0.86	1.85
7.1.4 The Costs of Aggressive Driving	7.86	0.61	1.31
7.1.5 Reducing Speed	5.54	0.43	0.92
7.1.6 E-commerce	0.00	0.00	
7.1.7 Public Transportation	12.88	1.00	2.15
7.1.8 Carpooling	33.49	2.61	5.58
7.1.9 Telecommuting	57.97	4.52	9.66
7.1.10 Extreme Scenario	63.12	4.92	10.52

Personal transportation accounts for the greatest fraction of individual energy use, but also has the potential for the greatest savings. Through the complete omission of driving and use of public transportation an individual can consume no energy related to personal transportation. Due to demographics and circumstances such as the distance one lives to work, availability of those travelling similar routes or whether or not an opportunity to telecommute is viable all impact how much an individual can reduce their personal energy consumption. Despite potential obstacles it is not unreasonable for individuals to make use of the suggested driving strategies such as: proper tire maintenance, elimination of unnecessary idling, reducing the amount air conditioning is used, monitoring amount of aggressive driving and limiting highway speed. Using the data summarized in Table 8.12 and assuming that some of these practices are already used to a degree and not all are fully implemented, it is not outrageous to assume that energy savings could be around 14.43 million BTU per person per year or 2.41 BOE for anyone interested in reducing their personal energy consumption. Other energy saving strategies in the energy section such as the use of carpooling or public transportation are mutually exclusive so unlike the savings from driving habits then cannot be added together. It is also important to note that it is unlikely to achieve savings of 28.86 million BTU per person per year due to the interaction of vehicle functions, the range of potential savings and the various starting places for individuals wishing to implement these strategies. For example, not everyone drives extremely aggressively , with constant speeding up and slowing down those that currently drive more aggressively are facing more penalties for their driving behaviors and therefore have the ability to achieve greater savings.

Table 8.13: Data is a yearly average on a per capita basis. For the purpose of this table household operations are the activities done in an individual's home for the preparation of food. Food source refers to eating food prepared in the home, rather than eating processed or restaurant food. Animal products refer to reducing the amount of dietary animal products, such as mean, eggs, milk, and cheese. The total energy used in food production and consumption is assumed to approximately 46,811,791 BTU per person per year. CO_2 emissions assumed reduced by the same proportion as the energy used for each sector. CO_2 emission numbers were calculated from (Brower & Leon, 2009).

Proposal	million BTU saved per year per person	metric tons of CO_2 saved	barrels of oil equivalent saved (per person per year)	CO_2 per person equivalent
7.2.1 Household Operations	1.28	0.187	0.221	0.011
7.2.2 Food Source	4.68	0.816	0.808	0.044
7.2.3 Animal Products	8.47	0.048	1.46	0.0027

Energy can be saved in the food system by smart choice of what food is eaten, where that food comes from, and how that food is prepared. In the extreme case, an individual would consume only raw plant products, without consuming processed food or food from restaurants. The average individual has plenty of opportunity to save energy without resorting to the extreme. Household operations alone accounts for over a quarter of the energy used in the food sector, and one fifth of that energy comes directly from the use of cooking appliances. Replacing boiling as a cooking method with simmering or steaming, wherever possible, can be paired with diligent application of the passive cooking technique to save a reasonable 50% of cooking energy. Eliminating half of cooking energy, which is one fifth of household operation energy, would save 1.28 million BTU per person per year. Different sources of food have different energy impacts; processed food and food from restaurants have a much larger energy impact than fresh food prepared at home. About a quarter of the energy in the food system is used to prepare food for the consumer. By removing two out of every five restaurant or processed meals, an individual may save 10% of the energy used for the preparation of that food, which would average around 4.68 million BTU per person per year. Food produced from animal byproducts consume more energy than their plant counterparts. Producing animal products accounts for 18.1% of the food energy use as a whole. By reducing meat consumption by four sevenths, the equivalent of a daily meat eater eating meat only three times a week, energy savings would average 8.47 million BTU per person per year. The proposed strategies were designed to be as reasonable as possible, while still saving a significant amount of energy per person per year.

Table 8.14: Energy and waste savings comparison of the different strategies related to climate control. The different strategies are dynamic thermostat changes where the temperature is changed for 14 hours a day, static thermostat changes where the temperature is changed for a full 24 hours a day, and closing the blinds means keeping the blinds shut all day. This data is based on the assumption that the average number of people in a household is 2.61, a BOE is 6 million BTU, and the data is all calculated using the EPA calculator (U.S. EPA, 2004) to keep the baseline the same for the purpose of accurate comparison.

Proposal	Million BTU saved per year per person	Metric tons of CO_2 saved	Barrels of Oil Equivalent saved (per person per year)
7.3.1 Dynamic Thermostat Changes	0.23 - 2.80	0.23 - 2.85	0.04 - 0.47
7.3.2 Static Thermostat Changes	0.73 - 3.98	0.74 - 4.05	0.12 - 0.66
7.3.3 Closing the Blinds	0.0174 - 0.0611	0.018 - 0.062	0.003 - 0.01

Climate control energy usage plays a major role in the overall energy savings a person can attain over the course of a year. Implementation of a small change to the thermostat temperature combined with the closing of blinds can result in savings up to 4 million BTU or 0.67 BOE per person per year. The potential energy savings can increase up to a level of the extreme case where the savings equate to 23.5 million BTU or 3.92 BOE per person per year. The extreme case demonstrates the potential of these energy saving strategies. There are several factors that affect the potential energy savings that can be attained, such as: location, size of house, energy efficiency of the house, and energy resource. The energy savings in climate control are limited by the comfort level of the inhabitants of the residence. If people living in a residence are less susceptible to discomfort based on thermal conditions, they can save more energy by taking the strategies closer to the extreme. If the residents are very susceptible to changes in temperature however, they are less likely to save as much energy because they are less likely to be able to withstand the same extents of temperature changes. Instead of looking at the most extreme possible savings, a range of savings for different cities under two and four degree temperature changes from the baseline was calculated using the EPA calculator (U.S. EPA, 2004). This range was calculated for the two main thermostat strategies and is listed above in Table 8.14 alongside the range of savings for the third proposal, closing the blinds, based on the window efficiency and type. Proposal 7.3.3 can be used in conjunction with either Proposal 7.3.1 or 7.3.2. The data in Table 8.14 above leads to an overall range of energy savings of 0.2474 million BTU, 0.041 BOE, to 4.04 million BTU, 0.67 BOE, per person per year. The average savings from Table 8.14 is approximately 1.97 million BTU, 0.33 BOE, based on the average of the savings from Proposals 7.3.1 and 7.3.2 in conjunction with the average of the savings from Proposal 7.3.3. Though these numbers seem small, they equate a range of 0.09% to 9% savings in climate control energy usage for a modest, nearly unnoticeable change in temperature.

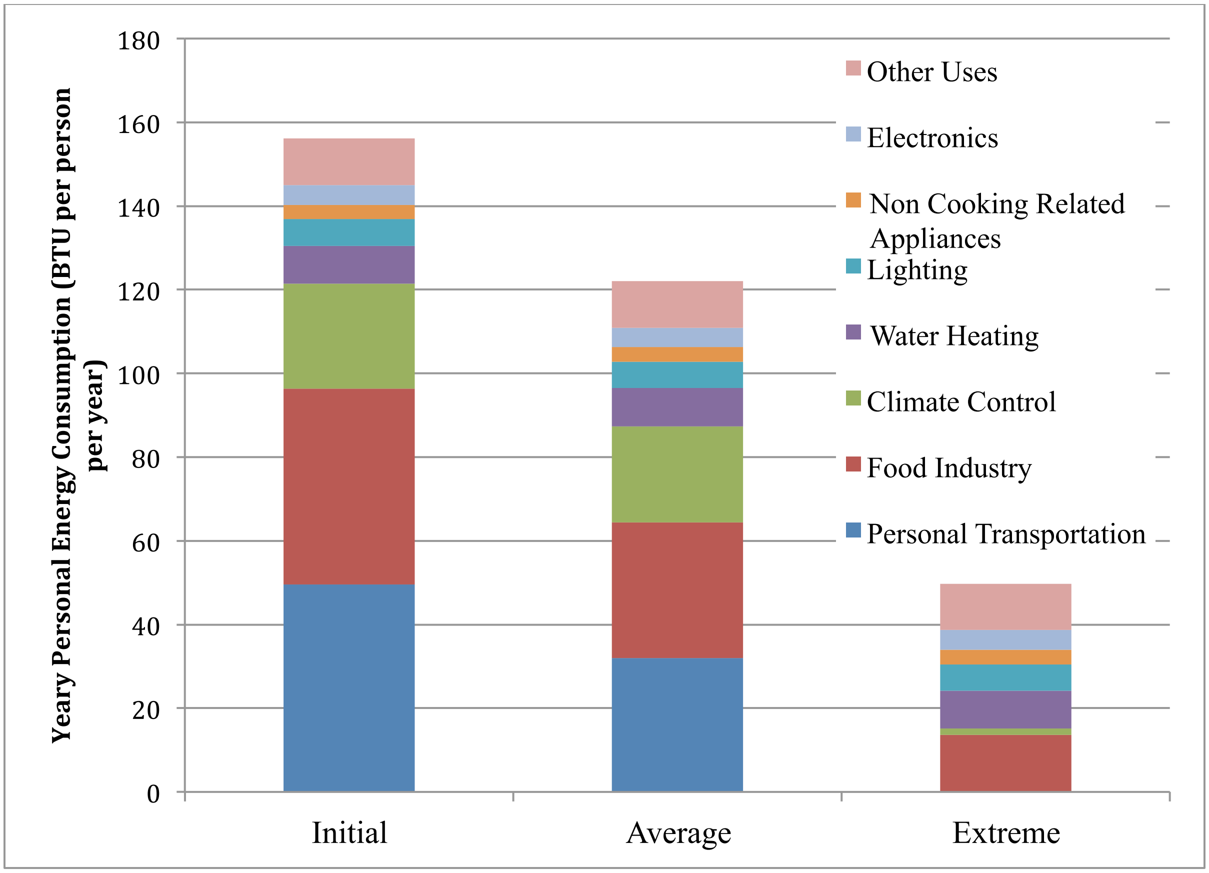

Figure 8.7: Comparison of overall energy usage, energy usage based on the average use of the suggested strategies, and energy usage based on the extreme maximum use of the suggested strategies. Average savings assume moderate implementation of the strategies with reasonable behavior modifications that only mildly impact the current way of life. The extreme savings come from elimination of personal transportation, consumption of fresh raw foods, and use of minimum and maximum thermostat set-up and setback temperatures. The adoption of the extreme strategies is much more likely to disrupt the current way of life, but in return offers a much more significant energy savings and consequently a much greater reduction in waste production and personal energy's monetary cost.

As great the energy savings can be through the implementation of energy saving strategies in one of the three high impact sectors alone the use of proposals from all three can provide noticeable for any willing to try. For example, if someone chose to take a middle of the road approach through slight modification of driving behaviors to drive more conservatively, reducing the amount of meat and processed food consumed and use of moderate climate control setback temperatures nearly 22% of energy consumption can be eliminated. This is on average equal to savings of 34.04 million BTU per person per year or 5.67 BOE and is illustrated in Figure 8.7 More drastic saving can be obtained by adopting the extreme scenario proposed for each sector. Estimations place the savings at around 68% reducing yearly energy consumption per person to 48.79 million BTU per year or 8.13 BOE. The savings at the per person level in turn affect the United States as a whole helping to achieve energy independence as the world searches for cleaner sources of energy.

9. Conclusion

Ultimately, using the various strategies described in each of the three highest energy consuming areas, climate control, transportation, and the food industry can help any individual reduce their energy consumption significantly. The specific amount of savings available can vary based on an individual's demographics and current habits but it is not outrageous to say that anyone can reduce their energy by at least 22%. This can be achieved by moderate changes including closely monitoring speed and acceleration while driving, using kitchen appliances significantly less, and using temperature setbacks and closing the blinds in a home. Much greater savings can be achieved through the integration of more energy saving proposals into daily life, such as omitting or significantly reducing driving a personal vehicle. This effort in turn has the potential to save the US enough on imports to provide the nation with sought after energy independence.

As the second highest energy consuming country in total, second only to China, and the fifteenth highest energy consuming country on a per capita basis United States citizens have the ability to drastically affect energy consumption . The citizens of the United States have the power to make a significant impact on the country's massive energy consumption. If everyone in the United States reduced their energy consumption by a modest average of 22% the United States could save approximately 10.6 quadrillion BTU (1.77 billion BOE), equivalent to approximately 60% of US imports for all crude oil and products (U.S. EIA). With this effort the United States would still be the second largest energy consuming country but would drop to seventeenth in energy consumption per capita. If everyone reduced their energy consumption by 68% using the extreme proposals for maximum energy savings the United States would become the twenty eighth largest energy consumer per capita (U.S. EIA).

In conjunction with reducing energy consumption, there is concern about CO_2 emissions contributing to global warming as well as a desire to make reserves of fossil fuels last longer as alternatives to energy production are becoming more viable. There are many different potential benefits and savings associated with the reduction of energy consumption that make the decision to follow some of the outlined proposals more appealing. The reduction of energy consumption has immediate benefits in the form of a reduced electricity bill and having to fill up one's vehicle less. Other benefits that cannot be seen overnight include the reduction of air pollution that accompanies the reduction of waste production. Finally, the reduction of energy consumption enables the US to reduce dependence on foreign imports which could ultimately reduce the cost of energy for us today. As a world leader, the United States has the ability to influence many other countries and lead by example to spread the effort of reducing energy consumption and waste production one BTU at a time.

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