3.003 - Principles of Engineering Practice

Project 3: Cutting Boston’s Energy Usage

Team eXtreme
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Introduction

In the year 2058, Boston will consume 375 million kilowatt hours of electricity alone. That’s more than 10% of all of the electric energy produced in Massachusetts! The energy usage is enormous and that figure doesn’t even include transportation. Take privately owned automobiles for instance. Right now, Bostonians sit in rush-hour traffic for more than 7 hours every day just to try to squeeze their gas guzzling cars into congested parking garages and nonexistent parking spaces. With concerns about energy resources on the rise, why do we simply throw away so much on a daily basis? Is it possible to reduce the amount of energy consumed in Boston?

These are the questions our group has struggled to answer over the past month of hard and arduous labor. Our initially proposed target was to reduce Boston’s energy consumption by 50% over the next 50 years, which should be fairly simple, seeing that Boston’s population has been relatively stable for the past decade or so at around 800 000 occupants. However, Boston’s energy consumption is increasing by 1.1% per annum as fewer people inhabit each house. (To understand the energy increase, simply realize that if the number of homes occupied doubles, the number of electric essentials such as refrigerators and ovens doubles.) Because the energy consumption graph has a fairly steady upward slope, our group thought it best—in fact only feasible—if we looked ahead at the projected energy consumption and decreased that by 50%. In short, our group hopes to have Boston consuming a mere 187.5 million kilowatt hours per annum, 86% of the 2006 power consumption.

In order to achieve this goal, we must modify the way people use energy without negatively impacting the way they live their everyday lives. The best possible place to start is to find the broken sections of our system and fix these.

The current state of transportation in the city of Boston would make an urban planner cry. The Massachusetts Bay Transportation Authority (MBTA) buses meet the standards for schedule adherence a mere 14% of the time. In 2004, there were 340 dropped trips (trips that were scheduled but not made).**footnote: This number has been steadily improving.** Only three of the eleven commuter rail trains and one of the four subway lines manage to stay on schedule. These lapses in public transportation are just a few examples of the quick yet long-term fixes that could lead to a reduction in total energy consumption.

As you read through our group’s extremely detailed and thorough recommendations, please be aware that we have decided to focus entirely on residential and commercial electrical usage (especially lighting) and transportation. We have left the extremely uncertain—possibly exponential—energy requirements for computers and industry out of our calculations. It is possible to reduce Boston’s 2058 energy consumption by 50% without taking either of these sectors into consideration.
### U.S. Energy End Use, by Sector:

<table>
<thead>
<tr>
<th>Sector Name</th>
<th>Description</th>
<th>Major Uses</th>
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| Industrial  | Facilities and equipment used for producing and processing goods. | 22% chemical production  
16% petroleum refining  
14% metal smelting/refining |
| Transportation | Vehicles which transport people/goods on ground, air or water. | 61% gasoline fuel  
21% diesel fuel  
12% aviation |
| Residential  | Living quarters for private households. | 32% space heating  
13% water heating  
12% lighting  
11% air conditioning  
8% refrigeration  
5% electronics  
5% wet-clean (mostly clothes dryers) |
| Commercial   | Service-providing facilities and equipment (businesses, government, other institutions). | 25% lighting  
13% heating  
11% cooling  
6% refrigeration  
6% water heating  
6% ventilation  
6% electronics |

http://en.wikipedia.org/wiki/Energy_use_in_the_United_States
Targeted Sectors: Transportation, Residential, Commercial

Targeted Uses: Non-aviation transportation, lighting, climate control (heating, cooling, etc.)

Energy Use in Targeted Sectors (nationally): 67%*17%+76%*21%+82%*28%=50.31%

Boston, as a city, has much less industry than average, and therefore a higher percentage of transportation and residential energy usage.

We believe that through reduction in the sectors outlined above, we can cut Boston's projected energy usage by 50%.

Lighting Recommendations

Our three-pronged attack to reduce energy usage from the lighting standpoint is a decrease in the overall number of light fixtures, a decrease in the usage of some of these light sources, and an increase in more efficient light fixtures via substitution. These will be enacted over immediate, short term, and long term time periods.

Immediate:

Boston has already begun reducing the number of light fixtures in its public sector. 103 light bulbs have already been removed from Town Hall (Lorenz 1). Strategically removing superfluous bulbs from large buildings is currently a highly underutilized tool for reducing the city’s energy usage. The number of bulbs removed is dependent on the current over illumination prevalent in such places as cosmetic stores, big box retailers, large company headquarters, etc. Furthermore, we plan to turn off street lamps in largely rural communities in the late hours of the night to the early hours of the morning. For each bulb that is shut off for about 3 hours every night (3am – 6am), we are saving 2 kWh per week. This is over 100 kWh per year for just 1 bulb.

Short Term:

Secondly, we will stimulate the replacement of incandescent bulbs with the more efficient fluorescent bulbs. Most large buildings (businesses, schools, etc…) already make use of these bulbs; our concern is dealing with the private sector. Compact fluorescent bulbs are readily available for home use and offer the same efficiency that their commercial relatives are known for. The current obstacle that we must hurdle is the initial cost of these bulbs. With incentives such as rebates and subsidies, fluorescent bulbs will become much more popular, as they do not require any other accompanying technology for the home (such as ballasts for high intensity discharge bulbs). Being that fluorescent bulbs are about 4 times more efficient than incandescent bulbs and last 8 times longer, the cost difference (an average of about $1.50) is easily covered by what would be the end of the lifetime of an incandescent bulb. The savings are accumulated by the increased efficiency and the longer lifetime.

Moreover, we will offer perks for companies that use less energy than the industry
average. These perks are negotiable; they can be monetary (tax deductions or contracts with public services) or non-material things (such as zoning preference). As companies strive to reduce their energy usage, the industry average will also lower, forcing companies to try harder and cut energy consumption even further. The idea that energy conservation has the potential to become competitive holds an optimistic future for energy savings. This of course would require very enticing perks which we have not stipulated in our proposal.

Similarly, to reduce consumption, we plan to implement a threshold tax for the private sector. Any energy consumption 50% above the national housing average will be heavily taxed to deter waste of lighting, heating, and cooling. Finally, we intend to continue with the replacement of traffic lights, exit signs, and lights of the like with LED’s.

**Long Term:**

In the future, we intend to monitor the advances in heating/cooling infrastructures as they are huge players in the consumption of energy and as of now there are no apparent optimal changes that can be widely implemented. In addition to this, OLED’s are fast becoming practical for household lighting use. They are becoming cheaper and more widespread (Wheel of Fortune™ used LED’s for its new wheel (Webber 2)). In addition to being very efficient, even more so than fluorescents, they also have the advantage of being environmentally friendly.

**Lighting Considerations**

There are varying social, economic, and political consequences to the recommendations we have made to reduce energy consumption. While these issues are not negligible, they do not detract significantly from the value of our plan.

We first propose to reduce lighting energy is to remove excess public lighting. This step is very feasible socially, economically, and politically because the only change is to remove existing items and consume less, as opposed to changing current bulbs. There is a possible problem of concerned citizens worried about lack of lighting, and therefore lack of safety, in parts of the city, but this could be allayed by a judicious choice of lighting removal. In short, this option is cheap and easy to implement, a perfect way to immediately reduce the amount of energy Boston spends on lighting.

In the short-term, we plan to replace inefficient older light bulbs with newer lights. By replacing lights, we would save money long-term because the new lights are both more efficient and have longer life-spans than current designs. The social issues to consider are people not liking the design of the new lights and lack of desire to change bulbs. The roots problems are aesthetics and apathy. As the bulbs are used more and more, more people will find the new bulbs to be ‘normal,’ and the designs will be
accepted. By a combination of rebates and time, all the bulbs will be replaced with newer models since current bulbs have a relatively short life-span. Economically, this proposal would have a high initial cost, but would pay for itself over the lifetime of the program. The main economic issue would be money for the rebates so poorer communities are not disenfranchised. Politically, replacing light bulbs is an attractive proposal because it is ‘green’ and few people are likely to oppose this measure. Replacing light bulbs is definitely a feasible option.

We will continue replacing public light bulbs. Because this program has already started, it has passed the social, economic, and political hurdles that could have prevented it and there is no reason not to continue.

We propose to have perks for energy efficiency within companies. Socially, this solution presents few challenges because the general public looks favorably upon trying to get industry to pollute less. The PR groups within companies will also try to use the perks to leverage new consumers. Economically, this proposal could cost the public money by reducing company and shareholder profits. However, it is definitely worth a little cost to greatly reduce the energy expenditures of industry. Politically, large companies may be against the proposal, but because it is only a positive measure (there are no repercussions for failing to meet the standard, only incentives for exceeding the standard) there are no insurmountable political obstacles. Implementing this proposal will be good for reducing energy at an acceptable cost to the public.

Our final short-term proposal is to implement a threshold tax for the private sector. This tax is the one with the most hurdles towards becoming a viable option. Socially and politically, this proposal is almost certainly impossible at face value. However, a closer look at the proposal – that it would only tax people for usage past a reasonable point – and the consequences would improve public perception. The consequences of this proposal are that people would pay taxes if they don’t conserve energy, through actions like turning off lights and unused appliances.

Economically, these actions would save people money and the threat of taxes would cause them to conserve even more to be sure they don’t incur the tax. To make this measure feasible, a PR campaign would be necessary to correctly educate the public about the proposal. Once passed, the idea would be easy to implement by simply monitoring energy usage through energy companies. This proposal would be hard to pass, but would greatly reduce the amount of energy the private sector uses.

Our long-term solution involves environmentally-friendly, ultra-efficient lighting that is currently under development – organic light-emitting diodes (OLEDs). This lighting has few real issues preventing large-scale adoption. Socially, OLEDs would require rethinking how lighting works because the lights would be large, thin membranes and so a whole ceiling or wall could be lit and provide both a TV screen and a light with low electricity usage. This usage is different than current lighting, which emits light from a fixed point. Once people are accustomed to the lighting, there are no more social obstacles.
Economically, OLEDs are currently very expensive. However, the cost has come down considerably the past few years and in twenty years it is not unreasonable to assume that the equivalent amount of lighting as a light bulb would cost the same. OLEDs are much more efficient and would save money and materials since they are totally recyclable. Politically, OLEDs are an attractive option because they are cheap and efficient without any group of people against them, so opposition will be slight. By using OLEDs, Boston can reduce energy consumption due to lighting considerably – enough to make our goal of 50% energy reduction.

Transportation Recommendations

Generally speaking, our recommendations aim to decrease the total number of commuters, and maximize the usage of public transportation. The rationale behind this decision is that fewer commuters require less energy, and that it is more efficient to transport groups of people than individuals.

Immediate:

Several actions can be taken in the immediate future. First, we suggest a general revamping of the MBTA, improving the reliability and efficiency of the system as a whole. If the buses are not on time or if they don’t get where people need them to go, there is little inclination to use the system. As it is, the system is unreliable, and lacks cross-town paths; it is a spindle, rather than the preferred spider-web, design. Through a combination of a budget increase and a redesign of bus routes, the transit system could be made much more appealing and hence more widely used.

Second, we recommend the implementation of two technical advancements as soon as possible: phasing the current vehicles out to be replaced with more fuel efficient models, and installing 'smart cards' in public transit vehicles which would give them right-of-way at intersections. Essentially, they would always have green lights, which would facilitate schedule reliability and shorten transit times while making it less desirable to drive a private car. A similar system has been implemented in several cities, such as West Midlands, UK.

Short Term:

Our short-term recommendations generally focus on tax restructuring, offering incentives to behave in energy-efficient ways. First and most simple, we suggest tax incentives for fuel-efficient cars, such as hybrids or the more fuel-efficient conventional vehicles. Second, we would provide tax incentives to promote ride-sharing and car-sharing services such as Zipcar, provided that the companies involved use only high-efficiency cars. This would kill two birds with one stone, reducing the number of cars in the city and making the remaining cars more efficient.
Finally, we would implement a congestion charge, forcing people who commute into Boston to pay to enter the city. This would reduce highway traffic while encouraging the use of transit systems like trains. Specifically, we would require the use of an RFID system (like EZ-Pass or other systems already in place in other cities), such that anyone getting off of I-93 between exits 15 and 26, or I-90 between exits 17 and 26, would pay a large toll, on the order of fifteen dollars. Locals – that is, anyone who lives within Boston city limits – would be exempt. A similar system was recently implemented in London, and seems effective. The revenue generated from this system would go to make public transportation either free or negligibly expensive to the end user, further encouraging its use.

Another action to be taken in the short term, though with an eye towards long-term effects, is the creation of taxes favorable to remote working or tele-working. Put simply, it is more energy-efficient (though not yet more cost efficient) to move information than to move people. If industry and corporations continue to shift into information technologies, it is not unreasonable to assume that the number of people who work from home will rise. Through the use of tax incentives, this can be encouraged, leading to fewer commuters, fewer cars on the road, less traffic, and less energy used overall.

Long Term:

Long-term recommendations are harder to pin down. It is a fair assumption that, given current research trends, there will be significant advances in the efficiency of automobiles; specifically, the present fuel-inefficient internal combustion engines will be replaced by some new system, such as fuel-cell technology or another as yet unseen innovation. Internal combustion engines waste over 80% the energy in their fuel; new technologies could lower that number significantly, ideally to less than 10%. This will slash the energy cost of personal transportation, further reducing energy usage, on top of the reduction from having fewer cars on the road.

Furthermore, in fifty years the Boston transportation system will be reaching its sesquicentennial anniversary. By that point, replacing it will be a necessity, not the unaffordable luxury it is now, so we assume that within fifty years an entirely new system will be installed. Designing that system would be impossible without knowing the realities of Boston and the advances in technology circa 2058, but assuming it is well-designed and efficient, the new system should drastically reduce the energy consumed in transportation.

Transportation Considerations

Since the main objectives of our recommendations for transportation are to take
advantage of public transit and lower the number of commuters, we anticipate a number of multidimensional issues. These issues to be addressed are considered in our immediate, short term, and long term transportation recommendations.

The recommendations to be enacted immediately pose the least problems since they are aimed at improving Boston’s public transportation system without undergoing complete overhaul. Thus, revamping MBTA transportation should be well accepted by the general public. The first improvement would result in redrawn bus routes, shifting from the current spindle arrangement to a “spider-web” design for more cross-town access. As the public transit system would then become more efficient, accessible, and convenient, we expect little opposition to this plan. However, any concerns regarding which neighborhoods the routes will run through must be addressed. Keeping this in mind, the system will be updated and redesigned to provide more public transit flow to areas that need it without isolating any currently serviced area.

The other two immediate improvements are of a more technological nature. Our plan to phase out current public transit vehicles with more fuel-efficient models should take the shape of lobbying for “greener” mass transit, a move we intend to make with no social opposition but against some initial political inertia—perhaps due to the management of the City’s budget or the legislative influence of the MBTA. We foresee the implementation of a “smart card” system for public transit to be an even smoother upgrade, adding to efficiency the MBTA can market to increase ridership.

In addition to the immediate considerations, there are also several points of discussion for the short term solutions, especially since our short term recommendations chiefly depend on economic maneuvering. Among our short term recommendations for transportation, the adoption of a congestion fee is the most economically dependent. We expect to encounter political hurdles along the road to better transportation, and it may be difficult to get the congestion fee approved due to its political and economical unfriendliness. Politicians may have trouble getting voters to swallow a congestion fee, and the less financially fortunate may find themselves at odds with a booth that charges them to cross into Boston regions. If these issues are left unaddressed, the proposal may even prove socially problematic as individuals begin to feel unwelcome into areas they frequent—at least while riding in their vehicles.

However, although this fee may prove difficult to establish, we expect it to garner support through our considerate specifications. As an integral condition for establishing the fee and maintaining a functioning and satisfied population, citizens within certain boundaries will be exempt from the congestion charge. The addition of a “buffer zone” should also contribute to a fair fee system by drawing the boundary lines based on logistics more than on rigid Boston city boundaries. Moreover, hesitant citizenry will be more easily convinced to adopt the congestion fee knowing that profits generated from it will go toward making public transportation as inexpensive as possible. This last clause has much potential since our goal is not to generate money but to reduce energy consumption. The congestion fee should also work exceptionally well on the technological level. The advantages of RFID technology will allow for an expansive,
well monitored system, and the technology won’t be problematic at such late stages in its development.

For the short term, we also propose changes to the more private realms of transportation. Our straightforward plan to offer tax incentives to encourage drivers to use hybrid and fuel-efficient vehicles should be well-accepted. The social implications are positive, for the city will support all those individuals who want to help the situation and themselves. From the start, the tax incentive would easily make fuel-efficient cars more affordable. We’d also like to encourage that shift in the private car-sharing and ride-sharing industry. The strategy would be essentially the same: by offering tax incentives to companies like Zipcar, we can foster an industry that uses highly efficient vehicles. Like the tax incentive for individual drivers, this program would not punish for energy consumption but instead promote better energy use. As for nurturing a culture of tele-workers through tax incentive, we predict similar favorable results where many employees will conveniently opt to work from their home offices and commute less. This positive trend is already developing without the need for incentives, so strategic tax incentives should make the change in work habits even more effortless.

In our plans, we have also anticipated a few potential issues en route to employing our long-term recommendations; however, these deal more with the uncertainty of the future than with specific plans. One major recommendation we make regards the whole Boston transportation system. In that scenario, we expect an extensive replacement or revamping of system sometime in the future. Such long-term projects would significantly impact our plans to reduce energy consumption, and it is crucial that we be wary of such future large-scale changes when drafting plans for future energy management. In this way, we at least can prepare mitigation methods and shape the plans to favor the reduction of energy use. Our reasonable prediction that current internal combustion engines will be replaced by some new, more efficient system is another example of how we can exploit those variables of the future to reach our energy goals. The goal to keep in mind when making recommendations for the long-term is that whatever drastic changes in tide, we can manipulate them to improve our plan of attack against energy consumption.

Conclusion

Our project focused on lowering the energy consumption of Boston by reducing the amount of energy used by lighting and transportation. In the lighting sector, we used a combination of new lighting technology and government-based incentives to promote efficiency and conservation. Based on current technology, replacing all incandescent light bulbs would increase efficiency by 400%, not to mention the cost of unnecessary replacement bulbs. With technology such as OLEDs on the horizon, it can be reasonably assumed that the efficiency will double, though exact numbers are impossible to calculate because of the novelty of this technology. Climate control technology is harder to gauge,
but we expect at least a threefold increase in efficiency within fifty years. Conservation has been demonstrated to reduce energy consumption greatly, but we expect at least 40% reduction in electrical usage, including other climate control factors. Lighting and other climate control measures currently account for a little under 30% of Boston’s energy usage, and we expect the amount of energy to increase by 1.1% each year. Through our long-term goals, we believe that we will save over 90% of that energy. By our lighting measures, we can reduce the projected energy usage of Boston in 2058 by 25%.

In our transportation plan, we focus on reducing private transportation and increasing reliance on self or public transportation, while simultaneously increasing the efficiency of both private and public vehicles. We expect a net decrease in commuters and depend on teleworking to be a contributing factor in removing 15% of commuters by 2058. Based on results of London’s congestion fee, which saw a decrease of 16% in traffic, we expect similar results from our program. The commuters will instead take public transportation. As the MBTA is re-routed to better serve the Boston community, we expect another 10% of private commuters to switch to public transportation given the high price of gas. For the remaining cars, the introduction of a more efficient engine, which could easily be four times as efficient within 50 years, will greatly reduce the transportation energy usage. Along with the MBTA redesign, we will improve efficiency by making sure routes run on time and cutting unnecessary runs to lower energy costs. Through these innovations and the eventual introduction of state-of-the-art mass transit, we expect the energy consumption of public transportation to be at least four times more efficient. Transportation is over 30% of the energy costs for Boston, and we expect to save most of that energy with our plan. If we implement our procedures, we will save another 25% of the projected energy usage of Boston by 2058.

Our plans have many hurdles before they can be implemented, but they represent the best way to reduce the energy usage in Boston by 2058. Combined, they will cut energy usage by 50% of current projections and lead to a net decrease in energy usage from the present day. In a world of increasing resource competition, it is important to maintain efficiency and sustainability, and our project provides a view of a cleaner, less wasteful future Boston.