Worcester Polytechnic Institute

Interactive Qualifying Project (IQP)
Economic Analysis on Demand Response

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Abstract:

This paper will analyze the data retrieved from the survey written and circulated by the Demand Response IQP team. The goal is to determine the possible implementation of a demand response program in the Greater Boston Area. Using the historical data ISO publishes on there website along with the data from the survey a model of how the demand relates to the price of energy this paper will determine if there is profit in demand response in this region.

1. Economic Analysis:

The goal of this section is to enumerate the other economic and environmental impacts of a demand response program in the Greater Boston Area.

To accomplish this goal several questions of the survey were used. One survey question asked the respondents to answer how many air conditioners they had and whether they were an window unit or a central AC unit. Using this information we could determine, if the survey sample was unbiased how many residential homeowners have AC and the approximate BTU's of those air conditioners (by using average value of 10,000 BTU's per window unit and 36,000 Btu's for a Central AC). Another question in the survey that was utilized was the approximate incentive needed by respondents to choose the program 2 option mentioned in the survey. From this it could determined the approximate BTU's per incentive group and this could be calculated into a supply demand curve where the demand for program option two at different prices would be compared to what ISO New England could offer for these incentives.

Another aspect of economics that could be compared is the effect of the "wear and tear" on the power lines. Each time the power lines are used there is an effect of structural stability of the wires and obviously the more power that goes through the lines the more destructive the effect. When a demand response program is initiated the load that the lines carry is reduced and thus the "wear and tear" effect is reduced as well. Since demand response programs are reducing load at the peak power times their minimal reduction in the load is affecting the maintenance costs of the line much more then other times. Also since air conditioners motors have a power factor that is not unity, this also strains the ISO New England more then if it was purely a resistive load. Finally the fact because demand response programs are initiated the construction of new lines and power plants may not be necessary immediately. All these factors however, are beyond the scope of this project. However, The approximate amount of energy saved could be used later in a further project to estimate these costs.

The environmental impact of the demand response program can be seen directly as a function of energy saved. Each watt saved is a watt that would normally have to be produced and therefore saves the pollution associated with producing that electricity. This is of course assuming that demand response programs indeed save the energy and not that they shift energy usage towards off peak hours and there by flattening peak hours but increasing off peak hours. A further project would need to examine the effect that demand response programs have on actual energy usage.

1.1 Competition:

Competition is important to all markets when looking from the point of view of the consumer. Competition forces a supplier of a good or service to sell there product based on where the supply meets the demand. When there is no competition the supplier can set any price as long as the product is required by its users such as power. In most markets competition is formed by multiple companies creating a similar product that can fill the same purpose. When sold this product at market it will be purchased by a consumer based on price and history with manufacturer. The consumer is going to choose the product that fits their needs and has the lowest cost. However the consumer does not get to select between different power markets. Instead the competition between suppliers of power is created by ISO's capacity auctions. ISO-NE uses the demand trends of the past and a bit of weather prediction to forecast the demand needed in the future. This allows for power to be traded in advance. So ISO will tell the product manufacturers what it needs. The manufacturers will decide on a price of power for that time and day which will still make a profit. This system causes the power producers to compete against one another for better prices because each of these companies want to be producing power as often as possible to make money.

The demand response is going to impact competition in a few ways. The first way is that it essentially adds another competitor for power production. Demand response does not actually produce any power, however the energy that is not used because of it can be considered equivalent to power produced. So in other words Demand response reduces the total amount of power that can be sold by the power production companies.

This is because it allows the power plants to plan ahead for power needs. Due to the knowledge that plants will need to supply a specified amount at specified time the price of the energy is low. However it is not possible to predict the exact load required in advance. So the energy must be purchased at many intervals. Since you can't know the actual energy required to power the region it is inevitable that the purchase of power will be done in real time and day ahead. The cost of energy at the time of supply is far more expensive. This means that the consumer will end up paying more. The location marginal price or LMP is price per megawatt hour. This price describes the going rate for power at certain locations in the New England Area. In table 1.1 you can see how the average of the RT(real time) LMP is less then the DA(day ahead) LMP.

Hub/Zone/ Ext. Node	Avg DA LMP ($/MWh)	Avg RT LMP ($/MWh)	Min DA LMP ($/MWh)	Min RT LMP ($/MWh)	Max DA LMP ($/MWh)	Max RT LMP ($/MWh)
Hub	$81.30	$79.55	$42.63	$13.73	$142.76	$297.92
ME	$77.70	$75.88	$40.36	$13.30	$139.13	$287.88
NH	$80.18	$78.52	$42.12	$13.64	$141.82	$294.13
VT	$83.32	$80.92	$43.03	$13.80	$144.72	$297.65
CT	$84.22	$81.56	$43.00	$13.70	$144.72	$302.58
RI	$78.87	$77.57	$41.78	$13.43	$139.54	$294.40
SEMA	$80.12	$77.94	$42.07	$13.56	$140.13	$295.71
WCMA	$82.27	$80.24	$42.90	$13.82	$143.99	$300.10
NEMA	$78.96	$77.56	$41.93	$13.53	$140.53	$290.36
NB Ext	$75.93	$73.89	$39.20	$12.97	$135.82	$267.41
NY Ext	$83.52	$81.65	$42.74	$13.64	$144.20	$301.80
HQ Ext	$77.35	$76.01	$41.16	$13.37	$137.36	$286.68
HG Ext	$77.67	$75.79	$40.65	$13.03	$135.37	$274.97
CSC Ext	$83.59	$81.16	$43.04	$13.79	$144.63	$303.45

Table 1.1 LMP for grid for 2006(ISO-ne.com)

The important value to see here is the maximum real time LMP versus the day ahead LMP. From the graph in the introduction section it is clear that the LMP follows the MWh load. This means that the peak on the LMP is going to correspond to the load peak. The price per megawatt is over twice the max of the day ahead. Also the same trend happens on the min where the real time value is far less. The real time value has a higher variance. Economically we can look at this in terms of supply and demand. When the demand is low the plants will have the ability to produce far more then is needed. This makes it so power can come from many sources and when looking at this is real time the plants are likely to have some surplus which will degrade if not sold. So competition arises and the energy must be sold cheaply. On the high end the exact opposite happens. When the demand is high all the power sources are being strained for power. None of the plants will have surplus which then requires a large incentive to create more power.

Assuming the demand for power was constant at all time the price of power would not vary and the power sources would be able to produce exactly the right amount of energy decreasing lose. However this is not possible, but all these issues discussed above are problems cause by the peak of power reaching a peak that pushes suppliers and grids to the limit. Since we can't make demand constant the direct solution left to this problem is demand response which will take the strain off the system by decrease the demands on it. This will have a huge economic for the consumer because it will decrease use of power during the peak price periods. The price of power will be decreased further by decreasing the strain on the system allowing for more surplus and cheaper energy during the peaks.

1.2 General Analysis:

The supply curve is needed for any economic analysis of this program. If the program is viable it will be able to decrease the demand without increasing the LMP. Determining for this involved the relationship between the LMP and the demand for 2006. Using all the demand and LMP data from 2006 a model for the supply curve is created in relation to LMP and not total cost. The LMP is used instead traditional total cost because this market is unique in that the cost per sold unit increases as the demand increases which is the opposite of most markets. It is also unique because the supplier does not decide the supplied amount of product but instead the customer does. Since this is the case the only curve involved in this economy is the supply curve. The demand in this scenario is not fixed curve but is instead a fixed value that changes based on time.

From the historical data ISO publishes on there website a model of demand can be created by averaging the all the load data and LMP data at each hour. This gives an average load and LMP at each hour which then needs to be arranged by increasing LMP. This shows the general trend of our supply curve which will allow us to create a model of the demand that will follow the trend and allow for pricing based on percent of shown peak. To determine this we use simple filtering and polynomial fitting to create and equation to define the line. Figure 1.1 shows the trend of the demand if the hours were organized so that the LMP was increasing. Figure 1.2 shows the LMP in the same order as the demand

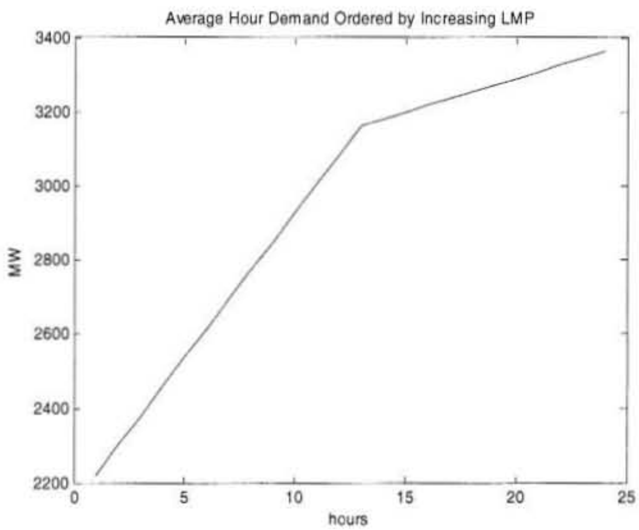


Figure 1.1 Filtered Demand Curve

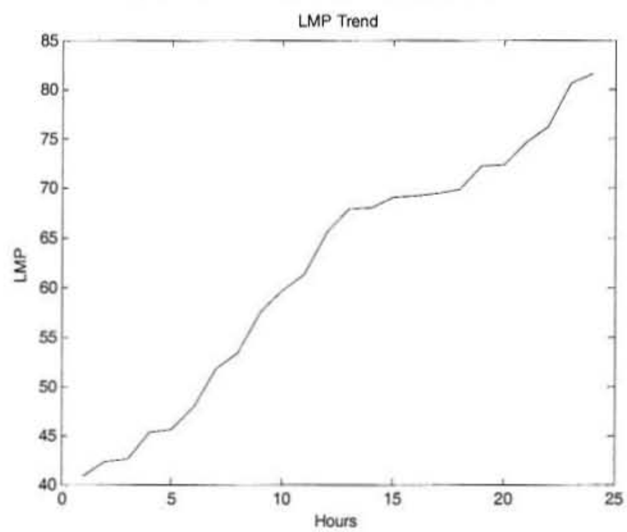


Figure 1.2 LMP Trend

These 2 graphs can be combined to show the demand Vs price. These could be related without being ordered, however this was done so that the demand curve could be straightened. To do so the values needed to be ordered by increasing LMP and then the best curve fit was found to replace the slightly noisy ordered demand curve.

The standard supply Vs demand graph involves a supply curve which describes the relation of price of a product to the amount sold. Figure 1.3 shows the supply curve for this market in terms of percentage of max LMP and the percentage of Max demand.

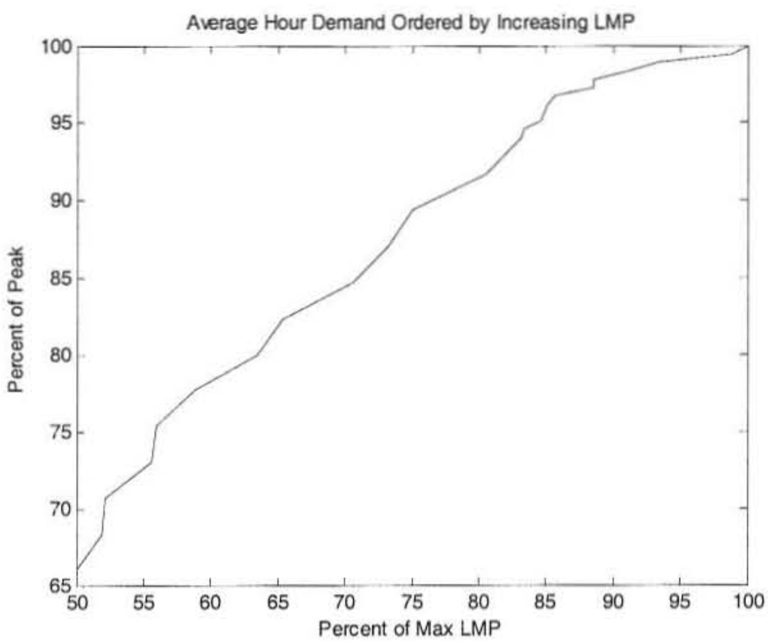


Figure 1.3 Supply Curve

Using Matlab the vector describing the data can be converted into an equation where the y signifies the LMP. The x is the demand which allows us to enter a demand and receive the LMP for that level of demand.

Equation 1: $$y = 0.0243x^2 - 2.7025x + 122.8073$$

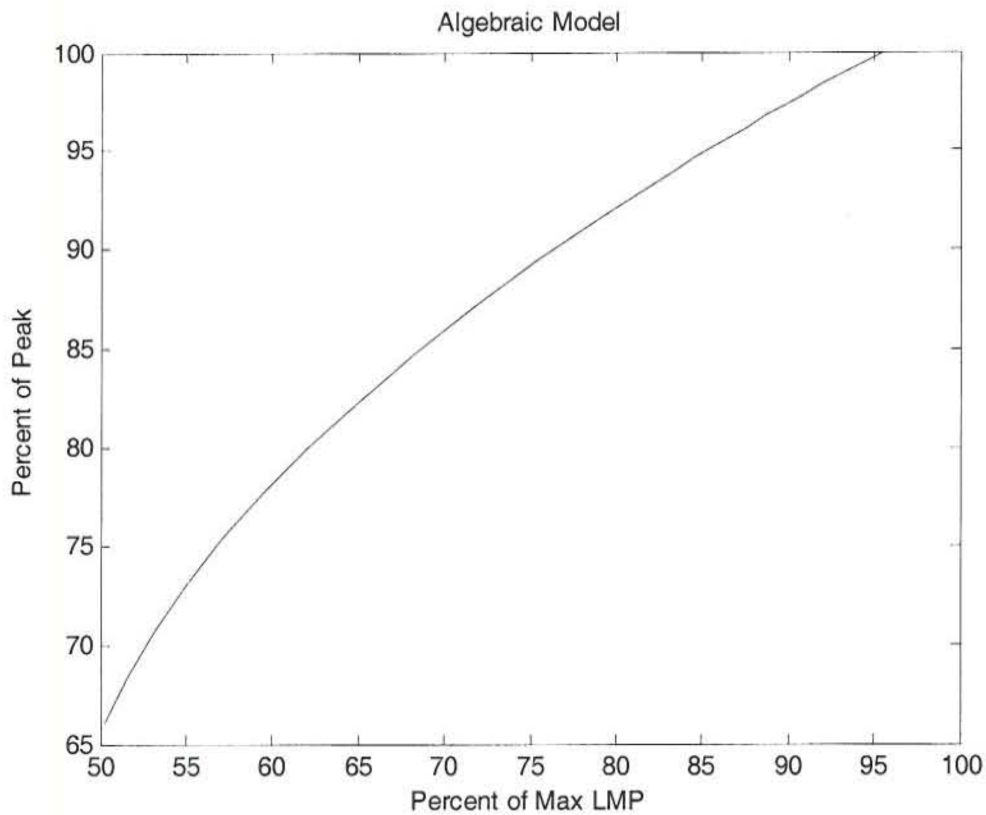


Figure 1.4 Algebraic Representation of supply curve

This equation is defined by the curve in Figure 1.3 using Matlab's Polyfit command. Figure 1.4 shows the graph of the equation that fits the curve. This equation will allow for a analysis of any day.

If a demand response program were to be used in the Boston Area it would decrease the amount of energy consumed by a certain percent. Our goal here is to see how much can be reduced if a certain percent of AC consumers use this program. Figure

1.5 shows a possible response to Demand response with each curve showing a different percent of households who own an AC involved.

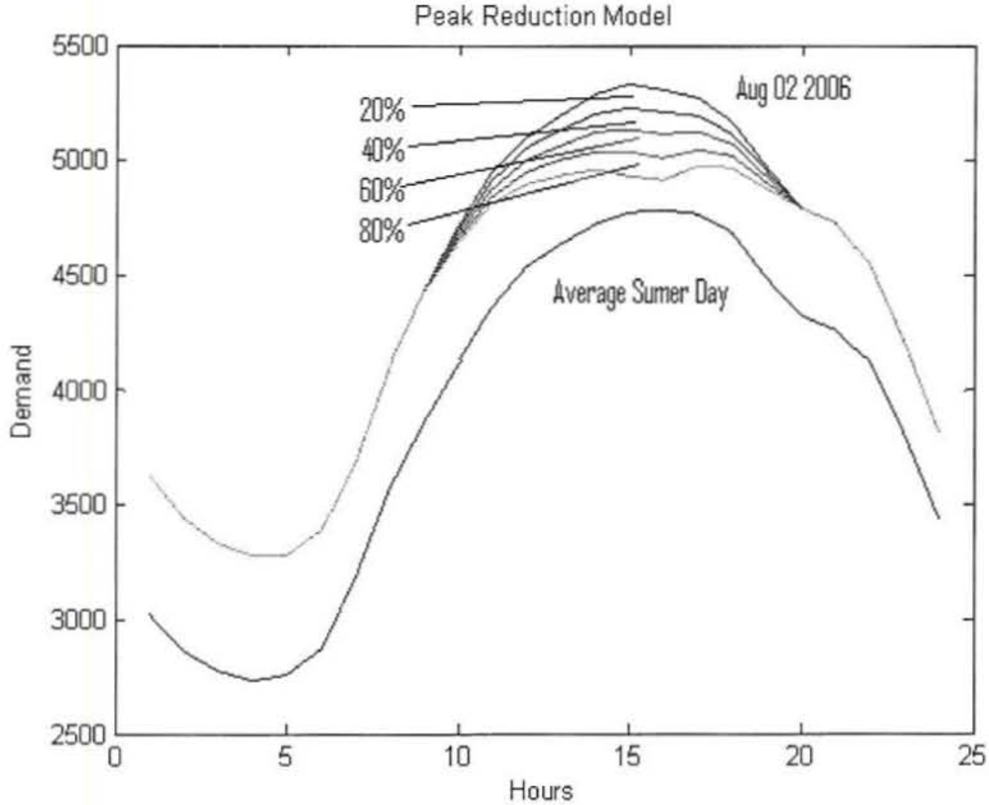


Figure 1.5 Peak Reduction Model

This model shows the different possible reductions in peak based on the percentage of AC consumers involved. The reductions are based on AC statistics and the percentage of people with certain AC's based on the survey which is discussed further latter on. For now the amount of money saved based on this model is the focus.

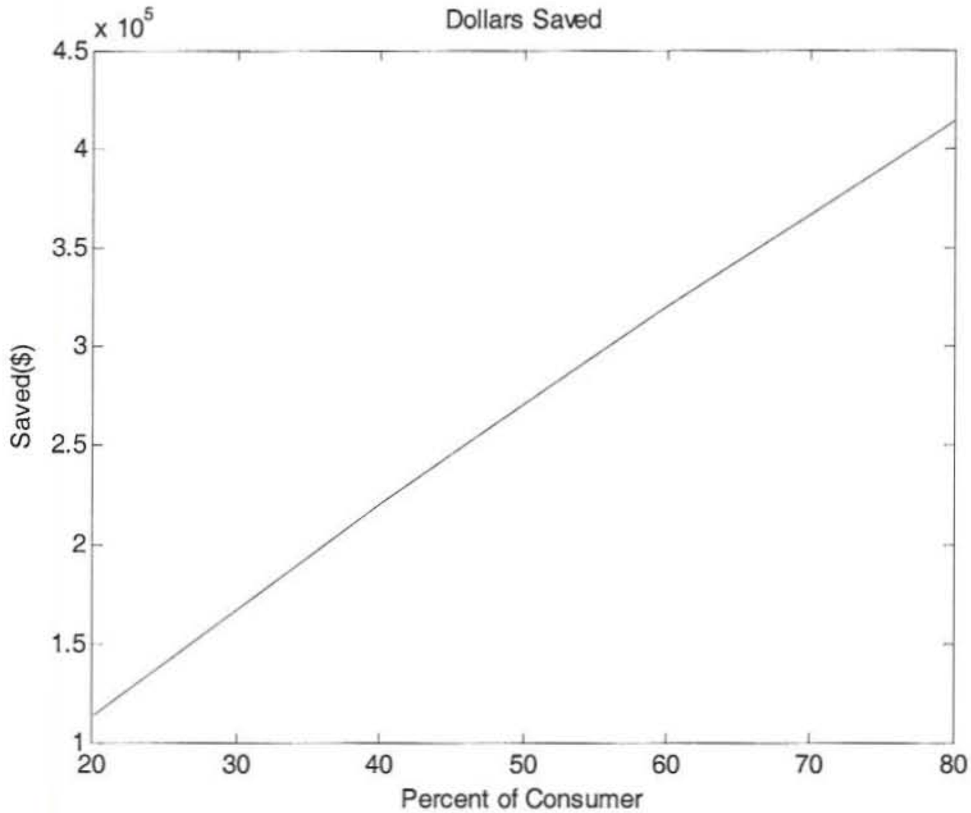


Figure 1.6 Amount of Money Saved

This shows the amount oh money that can be saved in one day of the program running on a hot day in the Greater Boston Area.

1.3 Energy potential:

The goal behind the demand response program is to allow ISO to initiate the system during peak hours and decrease the demand for power. When this system is initiated the air conditioners connected to there system will begin to cycle on and off reducing the energy used by that unit by 50% assuming a 50% duty cycle is used to turn on and off the air conditioners. The program will start and during the first minute of the programs initiation only 1/60 of the users will be switched off and the next 1/60 of the users will be shut off. This is to allow for a continuous demand response which is important because if the system shuts half off all at the same time and then alternates the demand on both groups will be different. Also if it switches all units at the same time there will be an impulse of power which will be difficult on the system.

Since the units are staggered there will be a startup and cool down periods. We know during the first 30 minutes we have a startup period which will increase the energy reduction by 1/30 of the total each minute. During the cool down the will decrease the energy demand by 1/30 of the total every minute until all air conditioners are running for a full cycle.

We can approximate the total possible energy used if we were turn on all the peoples ACs who responded with interest in this program. On the survey we asked what type of air conditioner the person had at home. The question on asked whether the unit was a window or a whole house AC to make it easier for the person surveyed. Air conditioners are sold in with a Btu's/hr rating which sets them apart from the next. Most window air conditioners are rated between 5,000 and 15,000 Btu's/hr. So for those how answered for window ac we can approximate the average to be 10,000 Btu's/hr. For those with the whole house ac we will use 36,000 Btu's/hr.

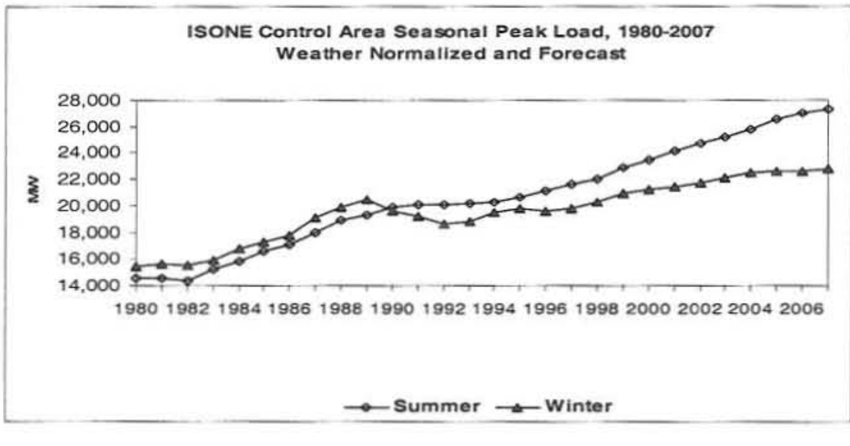
To determine each households potential energy use persons AC type was equated to a certain quantity of Btu's/hr. That amount was multiplied by the number of AC's the person owned. Now that this contribution is known each household they can be summed up based on the incentive that that person required which will then be equivalent to the amount of energy saved in Btu's/hr assuming that a program is created using that level of incentive. Table 1.2 shows the energy saved for each incentive level for the people survey and for all those in the Greater Boston Area. These values assume that we completely shut off the air conditioners used by the people at the homes responding.

	For Survey Consumers		For Greater Boston Area	
	Total BTUs	Total MWh		Total MWh
Incentive	Saved	Saved	Total BTUs Saved	Saved
Dollars	BTU/hr	MWh	BTU/hr	MWh
$0	450000	0.131882006	4603377273	1349.116954
$20-	530000	0.155327696	5421755455	1588.959968
$20-$30	750000	0.219803343	7672295455	2248.528257
$30-$39	920000	0.269625435	9411349091	2758.194662
$40-$49	1110000	0.325308948	11354997273	3327.82182
$50+	1610000	0.471844511	16469860909	4826.840658
Population	1,800,432		Magnification	10229.72727
Surveyed	176	1 MWh =	3412141 BTU/hr	

Table 1.2 Energy used by those interested in Demand Response in Greater Boston Area

1.4 Energy Saved:

There are two important results caused by demand response that will impact the overall cost of power. The first is peak reduction which will reduce the amount of load required during peak hours. This is extremely important because each year the load peak increases which results in more power needing to be generated the next year. This graph shows the progression of the yearly load peak for one hour for the last 27 years.



This increasing peak costs money for everyone since more capacity needs to be added to the system. The other result is in reduced power directly from the demand response program. The results are reduction in fuel consumption, reduction in pollution from power production, and reduction in the number of outages due to inability to meet demand.

Since the amount of power that can be saved can only be a portion of what is used we must start with some assumptions about the households in question by taking the average. In this case we are unable to determine the level of insulation and practices of the households in Boston. So we assume at 10 degrees difference in temperature outside as the set thermostat it requires an 85% duty cycle. If the temperature were to rise the air conditioner would need to work more often increasing the required duty cycle. To determine how much the person is going to use there air conditioner the day's temperature also plays a role. The demand response program will cut back the duty cycle to 50%. So as the temperature rises the amount of power that can be saved also rises. The two graphs below show the temperature and load by hour for July 2. This first graph also shows the estimated reduction for each of the incentive levels.

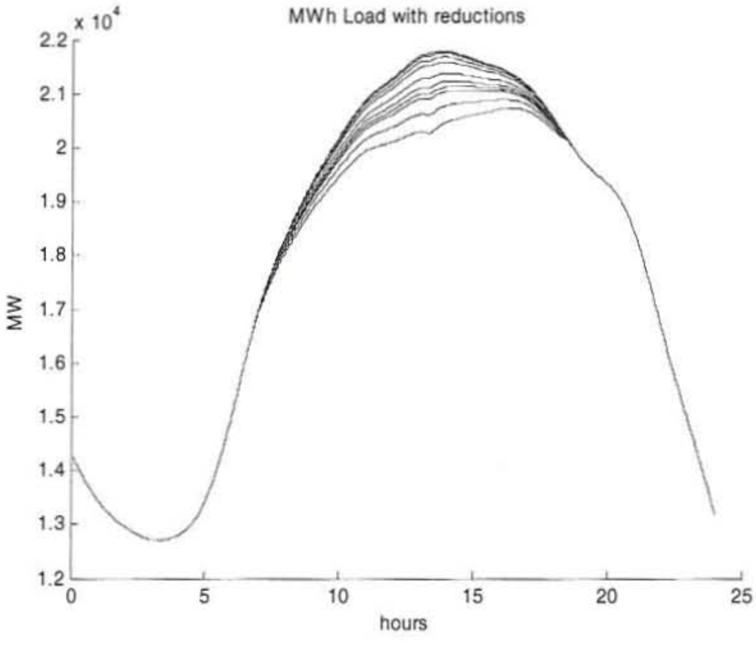


Figure 1.7 Possible Energy Reductions for July 02, 2006

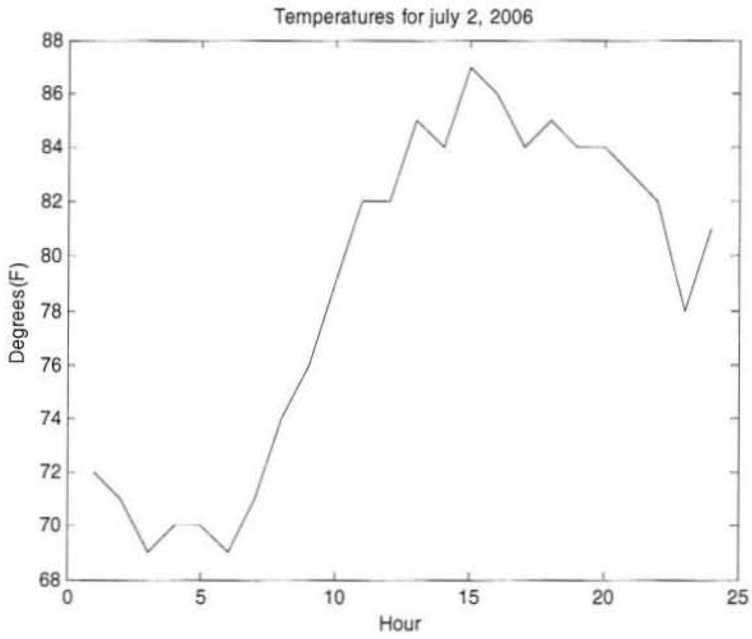


Figure 1.8 Temperatures for July 02, 2006

This gives an approximation of how many Megawatts can be decreased by each of the possible incentive levels. Using this model we can determine what percent of the peak can be decreased and the amount of power saved assuming the program is initiated an average number of times every year.

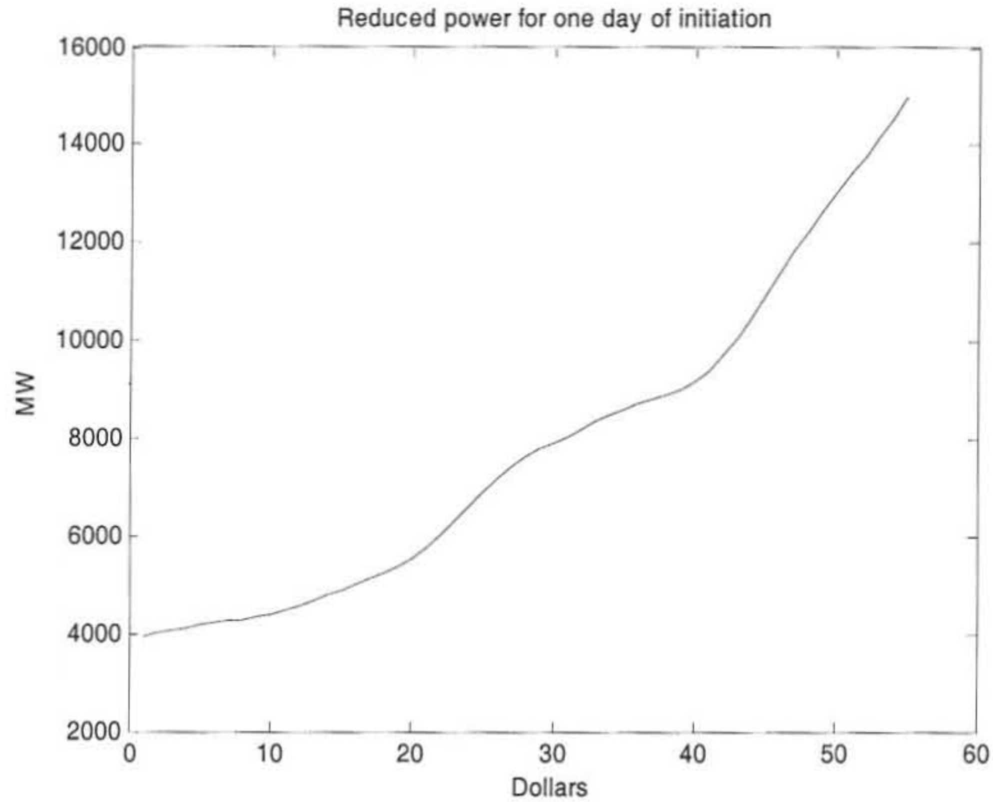


Figure 1.9 Total Energy Reduction

This reduction would be directly correlated to the amount of fuel used and pollution produced. The reductions from this reduction would be less depending on the number of people involved then .0006 % of the total amount consumed based the total amount of MWh distributed for the year(2.5e7) and the maximum of 1.5e4 MWh reduced.

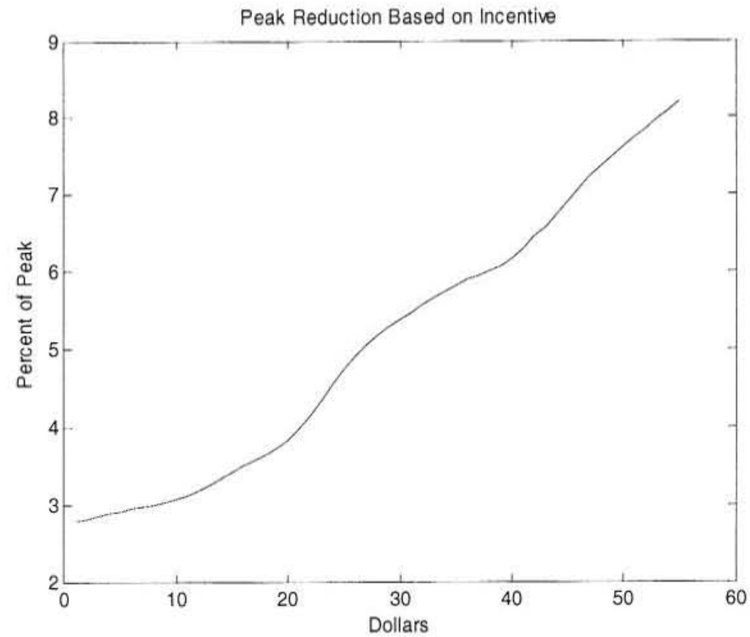


Figure 1.10 Peak Reduction Model

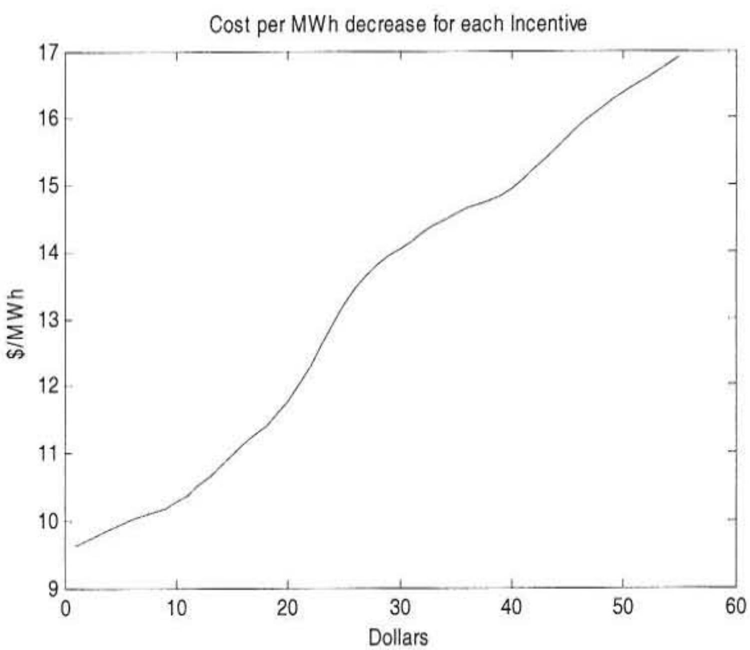


Figure 1.11 LMP Reduction Model

1.5 Incentive Conclusions:

On the hot days the LMP becomes far greater. On Aug 02 of last yeah the LMP rose to 250 for day ahead purchases. This means that if program giving out $5 to $10 dollars a month for the 3 hot summer months equaling a yearly incentive of $30 the company can expect to make a profit. According to the results a lower incentive could yield more profit however it would also would require more risk. These values are variable based on how much demand response is given for its equivalence of power reduction compared to the produced power. As a standard it is greater then if you consider that the demand response program is currently paid for its service and not for the reduction in power. For this model the best results would come from $10 for the reason that with less incentive advertising and maintenance cost would become to difficult to manage and $30 a year it gives people reason to continue the program. Figure 1.8 was created by taking the total saved subtracted by the estimated cost of the program.

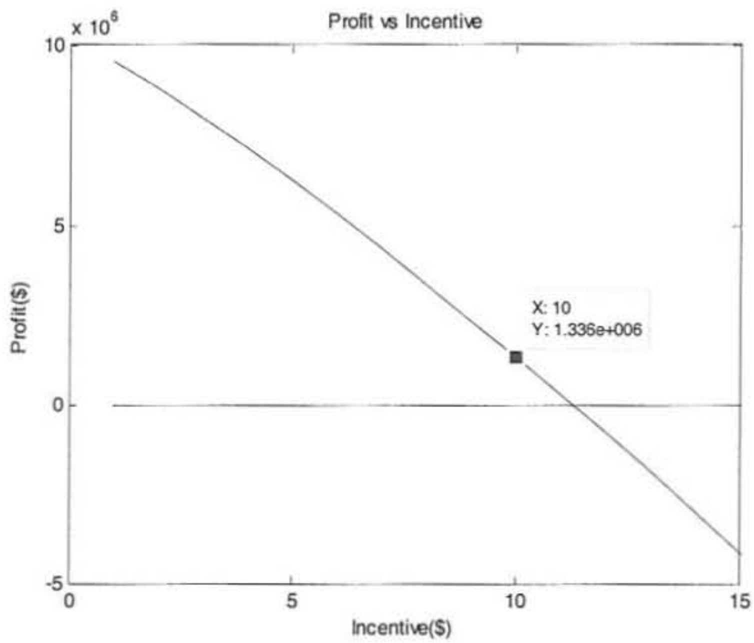


Figure 1.12 Profit

This program would account for 4395 MW of power and a 3% peak reduction for each day the program is engaged. This amount of decrease power also accounts for decreased pollution and decreased fuel. The decrease in peak will affect the upkeep costs of the power plants, transmission of power, energy loses, and new infrastructure. All of these costs become greater the more they are forced to stretch the power further then the equipment is used to. So by decreasing the peak the insurance, maintenance, and other overhead cost will drop in an annual sense. This same trend can be seen with the transmission of power because the system is not being pushed as hard as it can be it is less likely to fail which cost money to repair. This reduction in there areas is dependent on the LMP which changes based on competition and the risk the power plant factors into how much they can sell power for.

The reduction in the overall LMP is 10$/MWh with a $7 incentive plan. This is decreases the cost of energy not just for those involved in the production of energy, but also for all energy consumers. This is important for other reasons as well because it reduces waste in the system. This waste is equivalent to the LMP decrease is caused by needing new plants which increases competition. This also contributes with the increased maintenance costs of the system at both the plant and the transmission.

In conclusion this report supports the possibility of Demand Response programs in the Greater Boston Area. A Demand Response program will have a great impact on the production and transmission of power in this region in both cost benefits for the consumer but also benefit the environment and decrease upkeep costs of power production.

References:

ISO New England-Historical Data "ISO-ne.com"

Eyuel Abebe, Michael Irace, Jeffrey Tucker, Muzhtaba Tawkeer Islam, Chukwunomso Agunwamba, and James Chryssanthacopoulos "A Report on Demand Response"

Appendix

```
s = load('IQPdata.txt');

Type = s(:,7);      %contains AC type
Qty = s(:,8);      %contains AC quantity
inc = s(:,22);      %contains AC Incentive

int_count= zeros(6,1);  %number for each incentive lvl
per = zeros(6,1);

lvl = zeros(6,1);
lvl(1) = 0;
p = (length(s(:,7)'));
for n = 1:p
    if (inc(n) == 1)
        if (Type(n) == 1)
            if(Qty(n) ~= -1)
                lvl(1) = lvl(1) + (10000*Qty(n));   %sums the Amount of
BTUs
                int_count(1) = int_count(1) + 1;
            end
        end
        if (Type(n) ==2)
            if(Qty(n) ~= -1)
                lvl(1) = lvl(1) + (36000*Qty(n));   %sums the Amount of
BTUs
                int_count(1) = int_count(1) + 1;
            end
        end
        if (Type(n) ==3)
            if(Qty(n) ~= -1)
                lvl(1) = lvl(1) + ((10000+36000)*Qty(n)/2);   %sums the
Amount of BTUs
                int_count(1) = int_count(1) + 1;
            end
        end
    end
end
lvl(2) = lvl(1);
int_count(2) = int_count(1);
for n = 1:p
    if (inc(n) == 2)
        if (Type(n) == 1)
            if(Qty(n) ~= -1)
            lvl(2) = lvl(2) + (10000*Qty(n));   %sums the Amount of
BTUs
            int_count(2) = int_count(2) + 1;
            end
        end
        if (Type(n) ==2)
            if(Qty(n) ~= -1)
            lvl(2) = lvl(2) + (36000*Qty(n));   %sums the Amount of
BTUs
            int_count(2) = int_count(2) + 1;
            end
```

```
        if (Type(n) ==3)
            if(Qty(n) ~= -1)
                lvl(2) = lvl(2) + ((10000+36000)*Qty(n)/2);   %sums the
Amount of BTUs
                int_count(2) = int_count(2) + 1;
            end
        end
        end
    end
end
lvl(3) = lvl(2);
int_count(3) = int_count(2);
for n = 1:p
    if (inc(n) == 3)
        if (Type(n) == 1)
            if(Qty(n) ~= -1)
            lvl(3) = lvl(3) + (10000*Qty(n));   %sums the Amount of
BTUs
            int_count(3) = int_count(3) + 1;
            end
        end
        if (Type(n) ==2)
            if(Qty(n) ~= -1)
            lvl(3) = lvl(3) + (36000*Qty(n));   %sums the Amount of
BTUs
            int_count(3) = int_count(3) + 1;
            end
        end
        if (Type(n) ==3)
            if(Qty(n) ~= -1)
                lvl(3) = lvl(3) + ((10000+36000)*Qty(n)/2);   %sums the
Amount of BTUs
                int_count(3) = int_count(3) + 1;
            end
        end
    end
end
lvl(4) = lvl(3);
int_count(4) = int_count(3);
for n = 1:p
    if (inc(n) == 4)
        if (Type(n) == 1)
            if(Qty(n) ~= -1)
            lvl(4) = lvl(4) + (10000*Qty(n));   %sums the Amount of
BTUs
            int_count(4) = int_count(4) + 1;
            end
        end
        if (Type(n) ==2)
            if(Qty(n) ~= -1)
            lvl(4) = lvl(4) + (36000*Qty(n));   %sums the Amount of
BTUs
            int_count(4) = int_count(4) + 1;
            end
        end
        if (Type(n) ==3)
            if(Qty(n) ~= -1)
```

```
                lvl(4) = lvl(4) + ((10000+36000)*Qty(n)/2);   %sums the
Amount of BTUs
                int_count(4) = int_count(4) + 1;
            end
        end
    end
end
lvl(5) = lvl(4);
int_count(5) = int_count(4);
for n = 1:p
    if (inc(n) == 5)
        if (Type(n) == 1)
            if(Qty(n) ~= -1)
            lvl(5) = lvl(5) + (10000*Qty(n));   %sums the Amount of
BTUs
            int_count(5) = int_count(5) + 1;
            end
        end
        if (Type(n) ==2)
            if(Qty(n) ~= -1)
            lvl(5) = lvl(5) + (36000*Qty(n));   %sums the Amount of
BTUs
            int_count(5) = int_count(5) + 1;
            end
        end
        if (Type(n) ==3)
            if(Qty(n) ~= -1)
                lvl(5) = lvl(5) + ((10000+36000)*Qty(n)/2);   %sums the
Amount of BTUs
                int_count(5) = int_count(5) + 1;
            end
        end
    end
end
lvl(6) = lvl(5);
int_count(6) = int_count(5);
for n = 1:p
    if (inc(n) == 6)
        if (Type(n) == 1)
            if(Qty(n) ~= -1)
            lvl(6) = lvl(6) + (10000*Qty(n));   %sums the Amount of
BTUs
            int_count(6) = int_count(6) + 1;
            end
        end
        if (Type(n) ==2)
            if(Qty(n) ~= -1)
            lvl(6) = lvl(6) + (10000*Qty(n));   %sums the Amount of
BTUs
            int_count(6) = int_count(6) + 1;
            end
        end
        if (Type(n) ==3)
            if(Qty(n) ~= -1)
                lvl(6) = lvl(6) + ((10000+36000)*Qty(n)/2);   %sums the
Amount of BTUs
                int_count(6) = int_count(6) + 1;
```

```
            end
        end
    end
end
intlvl = zeros(11,1);
intlvl(1:2:11)=lvl;

intlvl(2) = (intlvl(1) + intlvl(3))/2;
intlvl(4) = (intlvl(3) + intlvl(5))/2;
intlvl(6) = (intlvl(5) + intlvl(7))/2;
intlvl(8) = (intlvl(7) + intlvl(9))/2;
intlvl(10) = (intlvl(9) + intlvl(11))/2;
intlvl2 = interp(intlvl,20);
lvl2 = zeros(11,1);
lvl2(1:3) = intlvl2(1:20:41);
lvl2(4) = intlvl2(54);
lvl2(5) = intlvl2(68);
lvl2(6:11) = intlvl(6:11);
intlvl = interp(lvl2,5);

count = zeros(11,1);
count(1:2:11)=int_count;

count(2) = (count(1) + count(3))/2;
count(4) = (count(3) + count(5))/2;
count(6) = (count(5) + count(7))/2;
count(8) = (count(7) + count(9))/2;
count(10) = (count(9) + count(11))/2;
count2 = interp(count,20);
count3 = zeros(11,1);
count3(1:3) = count2(1:20:41);
count3(4) = count2(54);
count3(5) = count2(68);
count3(6:11) = count(6:11);
int_count2 = interp(count3,5);

per_house = zeros(54,1);
l = 1:55;
cost = zeros(55,1);
cost = (int_count2*10230.* l'*3);

Costinc = zeros(55,1);
Costinc(2:55) = intlvl(2:55)*(10230/3412141) ./ cost(2:55);


%per_BTU = per_house ./ int_count;
figure(1);
plot(intlvl);
title('MWh reduced Vs dollar given');
xlabel('dollars');
ylabel('MWh');
figure(2);

plot(int_count2*10230);
title('Interested Vs dollar given');
```

```
xlabel('dollars');
ylabel('Households');
figure(3);
plot(cost);
title('Cost of program Vs dollar given');
xlabel('dollars');
ylabel('Cost of program');


load jul2.mat

t = (1:1:1440)/60;
MWhload = interp(jul2,60);

figure(4);
Watts = zeros(55,12);
func = zeros(420,1);
func = zeros(55,1);
conv = 10230/3412141;
mx = zeros(1,55);
for k = 1:55
    func(1:29) = (intlvl(k)*conv)*(1:29)/30;
    func(30:690) = (intlvl(k)*conv)/1;
    func(691:720) = (intlvl(k)*conv)*(1-(1:30)/30);
    func(1:400) = func(1:400) .* ((1:400)./1.1429e3)';
    func(401:720) = func(401:720) .* ((fliplr((1:320))./914.2857))';
    Watts(k,:) = func(1:60:720)';
    lnew = MWhload;
    lnew(401:1120) = MWhload(401:1120) - func(1:720)';
    hold on;
    g = k/5;
    if((g == 1) || (g == 2) || (g == 3) || (g == 4) || (g == 5) || (g
== 6) || (g == 7) || (g == 8) || (g == 9) || (g == 10))
        plot(t,lnew);
    end
    hold off;
    mx(k) = max(lnew)/max(MWhload);
end;
px = (1-(mx))*100;
title('MWh Load with reductions');
xlabel('hours');
ylabel('MW');

figure(6);
plot(Watts);
title('Percent of Reduced Power for one day of Initiation');
xlabel('Dollars');
ylabel('MW');

figure(7);
plot(px);
title('Peak Reduction Based on Incentive');
xlabel('Dollars');
ylabel('Percent of Peak');
```

```
load 'rtlmp.mat'
load 'demand.mat'

d = reshape(DEMAND,24,length(DEMAND)/24);
lrt = reshape(RT_LMP,24,length(RT_LMP)/24);
mlrt = mean(lrt');
md = mean(d');

omd = zeros(length(md),1);
olrt = zeros(length(md),1);
for p = 1:length(md+1)
    n = 1;
    while(n < length(md)+1)
        if min(mlrt) == mlrt(n)
            omd(p) = md(n);
            olrt(p) = mlrt(n);
            mlrt(n) = max(mlrt) + 1;
            n = length(md);
        else
            n = n + 1;
        end
    end
end

fmd = zeros(24,1);
fmd(1) = omd(1);
fmd(13) = omd(13);
for n = 2:13
    fmd(n) = fmd(1) + (n-1)*((fmd(13)-fmd(1))/13);
end

fmd(24) = omd(23);
for n = 1:12
    fmd(n+12) = fmd(13) + (n-1)*((fmd(24)-fmd(13))/11);
end
figure(8);
plot((olrt/max(olrt))*100,(fmd/max(fmd))*100);
title('Average Hour Demand Ordered by Increasing LMP');
xlabel('Percent of Max LMP');
ylabel('Percent of Peak');

save = zeros(55,1)
py = polyfit((fmd/max(fmd))*100,(olrt/max(olrt))*100,2)
g = polyval(py,(MWhload(401:60:1120)'./max(MWhload))*100);
for k = 1:55
   save(k) = sum(Watts(k,:) * g * 3,2);
end
j = max(olrt)- polyval(py,100-px);
figure(9);
plot(j);

%cw = cost'./(Watts*10);
figure(10)
plot(save)
title('Amount Saved vs Incentive');
xlabel('Incentive($)');
```

```
ylabel('Saved($)');

figure(11)
rev = save*10 - cost;
plot(rev)
title('Profit vs Incentive');
xlabel('Incentive($)');
ylabel('Profit($)');
hold on
plot(zeros(1,55))
hold off

figure(12)
plot(polyval(py,(fmd/max(fmd))*100),(fmd/max(fmd))*100)
title('Algebraic Model');
xlabel('Percent of Max LMP');
ylabel('Percent of Peak');

dhot = zeros(24,1);
dnorm = zeros(24,1);
chot = 0;
cnorm = 0;
for n = 1:365
    if (max(d(:,n)) > 5200)
        dhot = dhot + d(:,n);
        chot = chot + 1;
    else
        if (max(d(:,n)) > 4500)
            dnorm = dnorm + d(:,n);
            cnorm = cnorm + 1;
        end
    end
end

dhot = dhot / chot;
dnorm = dnorm / cnorm;
full = 10/(4000);
we = (1:4)/full;
wx = [(0:5)/20 fliplr((0:3))/12]';
mhot = repmat(dhot,1,4);
mhot(10:19,:) = mhot(10:19,:) - (wx*we);



g2 = polyval(py,(dhot(10:19)'./max(dhot))*100);
g1 = polyval(py,(mhot(10:19,1)'./max(dhot))*100);
g1 = 0;
wxwe = (wx*we);
ww = zeros(4,1);
for k = 1:4
   g1 = ( polyval(py,mhot(10:19,k)'./max(dhot(10:19))*100));
   ww(k) = sum(wxwe(:,k)' .*g1*.85*3)';
    figure(15);
    plot(g1)
    hold on
```

```
    g2 = polyval(py,mhot(10:19,k)'./max(dhot(10:19))*100);
end

figure(13);
plot(dhot)
hold on
plot(dnorm)
plot(mhot)
hold off

figure(14);
t = 20:20:80;
plot(t,ww);
title('Dollars Saved');
xlabel('Percent of Consumer');
ylabel('Saved($)');
```