Modeling the Future of Oil Consumption and The Feasibility of What We Can Do To Help

New Mexico
Supercomputing Challenge
Final Report
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Executive Summary

One of the greatest problems facing the world today is the Oil Crisis. The Oil Crisis, for our model's sake, is divided into two fundamental problems. First, the world currently consumes 80 million barrels of oil every year, yet there are only one trillion barrels of oil left in reserves. At this rate, the world will run out of oil in approximately 34 years. This poses a tremendous problem for future generations because oil has become a part of our modern lives, and without it or an alternate energy source, our standard of living would be diminished. In response the first fundamental problem, there are three different answers. One, continue to consume oil at the rate at which we are consuming now, and as a result, run out of oil in 34 years. Two, we can research and develop an alternative energy source to replace oil. Or third, we can adjust our consumption trend to a greater efficiency, thus prolonging the number of years which the amount of oil left in reserve may be available.

The second fundamental problem posed by the oil crisis is the perpetual disparity between oil consumptions amongst the world's 6.5 billion people (See Figure B-1). It is difficult to minutely differentiate between the developing world and the developed world, but the canonical values usually used are that:

- The developing world has 80% of the world's population and consumes 20% of its resources.
- The developed world has 20% of the world's population and consumes 80% of its resources.

These two fundamental problems are interrelated because if the rate at which oil is consumed decreases, the impoverished will consume even less. On the other hand, if the rate at which oil is consumed increases, then the general world oil consumption also increases, thus leading to the rapid depletion of oil. In an attempt to find a solution to these problems, we have developed a model to locate the balance between the two.

Introduction

Oil has been known about and used since the most ancient times. When we look back in time, the earliest oil well drilling was done in 4th century China. The Chinese burned oil to evaporate brine and produce salt. They undoubtedly used this extracted oil for lamps and probably, to a certain extent, to heat themselves and their dwellings. In the Western world, the petroleum industry began near Titusville, Pennsylvania, with Edwin Drake's discovery of oil in 1859. The new oil industry, the fuel oil and home heating oil industry, we know today, grew slowly in the 1800s and did not become a real national concern until the early part of the 20th century, when the use of oil overtook the use of coal.

Oils contain a high amount of stored energy, which can be used for heating and powering combustion engines. Oils used for this purpose are usually derived from petroleum, but biological sources of energy are being evaluated as an alternative to the increasingly expensive crude oil. Today about 90% of fuel needs are met by oil. Petroleum's worth as a portable, dense energy source that can powering the vast majority of vehicles and can act as the base of many industrial chemicals makes it one of the world's most important commodities.

After the recent, worldwide spark of interest in oil, due to the exorbitant gas prices, we also took an interest in oil, particularly, its consumption. Keeping up with news, and doing research, we developed a substantially grounded opinion on the subject. Once we heard of the Adventures in Supercomputing Challenge, we immediately saw our opportunity to make the world a better place with our knowledge of oil and computer science, while learning about team work, dedication, and leadership. We began by heavily researching the topic of oil consumption from all directions. We were able to assemble matched pairs of data for the populations and oil consumptions of 211 nations into two text files, which are read by our program. By graphing this information with our program, we observed a severe disparity between oil consumptions and the amount of people consuming in each range (See Figure B-1). Next, from our research, we learned that the Gross Domestic Product of each country is directly correlated with its oil consumption (See Figure A-1). A country's Gross domestic product, or GDP, is one of several measures of the size of its economy. The most common approach to measuring and understanding GDP is the expenditure method:

$$GDP = consumption + investment + exports - imports$$

With this knowledge, the meaning of Figure B-1 changed drastically. What the graph was telling us is that billions of people are impoverished. We immediately knew what we wanted to do for the Challenge. We decided to sequentially transform the graph of the status quo (Figure B-1) into a normal curve, with a specified center (X_0) and width (σ). Our goal was to see if we it was possible to move into this egalitarian state in 20 years, while still having half a trillion barrels left for consumption at the end. We chose 20 years because many scientists predict that current R&D will make an alternative energy source available as early as 2026, and it will be fully commercialized soon thereafter. Whether true or not, we limited ourselves to having half a trillion barrels left at the end of 2026, just in case R&D took longer than expected. If we could show that it is possible to move a multitude of people even one bin over on the x-axis, while keeping to our half a trillion barrel limit, we could show that it's possible to make the world a better place to live for billions, while still insuring the presence of oil for our youth.

Description and Method

Our program begins by graphing the current oil consumption situation. Then, it seeks to achieve our egalitarian state, defined mathematically by the normal bell shaped curve. We have several inputs, including the width of the final curve, the center of the final curve and the number of years we have to reach the final curve, which we've set to 20. Our original graph is a histogram graphing barrels per year per person vs. the amount of people consuming in that range of consumption rates. The current situation shows an exponentially decreasing histogram where many people consume a low amount and a select few consume a high amount of oil. We use an equation to fuse the current situation with our final situation over the specified number of years. We add the two equations (the status quo and the resulting state) as a function of the interval number of years, to find the function of oil being consumed at the interval of the number of years for our final state. We will sum the total amount of oil consumed for one interval. We will then sum each of these sums for the specified number of years to find the total amount of oil consumed over the period. To make the model more feasible, we will take into account the increasing world population.

The actual code accomplishes the above as follows. The consumptions and corresponding populations of 211 countries are read into a *vector*, converted to *double*s with the *atof()* function, and placed into *array*s, *consump[]* and *pop[]*. Next, the code cycles through each country and determines the highest and lowest consumption/capita/year, placing the values into *Xmax* and *Xmin*. The original intent was to use the *Xmax* our code came up with, however, we discovered that by doing so, our x-axis became distorted due to the presence of outliers, thus we set *Xmax* to 71. In the process, we eliminated around 360,000 people from our model (a miniscule amount in comparison to the overall world population). With the outliers removed, the code breaks the x-axis into 25 "bins", and sets the ranges of each bin with two arrays *Xleft[]*, which holds all of the min values for each bin, and *Xright[]*, which holds all of the max values for each bin. This mean that for some index, *Xleft[]* and *Xright[]* define a bin. Now that the bins of our x-axis are defined, the code cycles through the bins, and for each bin, it cycles through each country, calculating its oil consumption per capita per year. If it's consumption per capita per year fits in that bin's range, then that country's population is placed into that bin. The populations of the bins are represented by an array *popBin[]*, where each index represents a bin. Our code then sends this data, the status quo data, into an excel file, *StatQuo.xls*, which produces Figure B-1 when graphed.

Now that we have the status quo data established and ready for use, the code establishes everything necessary for our model to work. It defines *pHatN[]*, the proportion of the population that we want a bin, the index, to make up at the final state, and *pHat0[]*, the proportion of the population that a bin, the index of the array, makes up in the initial situation. Mathematically, each is defined as such when n is the number of years from now, N is the total number of years we are iterating through, X_i is the center of each bin i, X_0 is the center of our final normal curve, and σ is the half the width of that normal curve:

$$\hat{P}(X_i,0) = \frac{popBin(X_i,0)}{\sum_{i=0}^{25} popBin(X_i,0)}$$

$$\hat{P}(x_i, N) = \frac{e^{\frac{-(X_i - X_0)^2}{\sigma}}}{\sum_{i=0}^{25} e^{\frac{-(X_i - X_0)^2}{\sigma}}}$$

These values represent proportions, and are achieved through normalization, hence the presence of the summations. In our code, the summations occur before the definition of *pHat0[]*, and *pHatN[]*, because it would be impossible to simultaneously define the two in the same loop. Thus the summations used in normalization are defined as *totalPop* for the calculation of *pHat0[]*, and *sumE* for the calculation of *pHatN[]*.

With these two values defined, the code cycles through each bin, filling a new array, *popBinNew[][]*, where the first dimension represents the year of iteration and the second represents the bins, with the populations produces from our equation:

$$popBin(X_i, n) = totalPopAtYear\_n * (\hat{P}(x_i, 0) * (1 - \frac{n}{N}) + \hat{P}(x_i, N) * (\frac{n}{N}))$$

The equation is essentially fusing the situation for $n = 0$, with $n = N$. If $n = 0$, the population is split up into the bins according to the initial population proportions, *pHat0[]*. If $n = 20$, the population is split up into the bins according to the desired population proportions that will constitute the normal curve, *pHatN[]*. For an n value between 0 and 20, the equation linearly averages the two to get the population proportion of each bin for year n.

At the same time, it sequentially fills *totalConsumed*, with the amount of oil consumed in this 20 year cycle. All of this data is then sent to another Excel file, *Results.xls*, in a nice, neat format. All that's left is to open the file, check to see if the total amount of oil consumed is what is desired, highlight the results and produce a graph of your choice.

The receiving and sending of information in our code should be mentioned for clarification. The center of the desired normal curve is received as an input from the user at the beginning of the program. Also, the code uses an input file stream, *ifstream*, and two buffers: *ifs*, *ifss*, to receive information. To send information, the creates an Excel file with the *fopen* function, sends data to the file with *fprintf()*, and switches between columns and rows with *\t*, tab commands, and *\n*, new line commands.

Our model makes several assumptions. It assumes that all people, regardless of age, race, location, have the same capability of consuming oil. The model also assumes that all of the people in a country consume at the average rate of consumption, and thus we can use that average instead of stratifying the people of each country into consumption classes. In addition, our model assumes that the amount of oil that may be extracted is flexible and can adapt to however much the world needs; production is not an issue. Also, our model obviously assumes that there is a method, political or otherwise, for shifting the status quo to our desired egalitarian state. Our model also assumes that we will make a technological breakthrough by 2026, and fully commercialize it soon thereafter, which will bring forth an alternative energy source to ultimately replace oil.

The width of the curve, σ, is defined as ten percent of the value that represents the center of our curve. This is done to allow for a significant amount of variation amongst consumption levels since not all people can be expected to change. With sigma set to 10% of the center, our amount of bins set to 25, and our end year set to 2026, our program only deals with one parameter: the center of the normal curve (the average value of consumption that we want the world to consume at).

With the program ready and working perfectly, we will run the code for several centers, while seeing whether we will be able to consume an amount of oil less than or equal to half a trillion barrels of oil in the process of reaching a normal curve with our chosen center. We can accomplish several things here. First of all, we can see if the disparity amongst people is truly irreparable, or whether it can be fixed and all that's lacking is the politics. Second, we can see what the center can be if we were willing to consume down to exactly our half a trillion barrel limit. It is important to note that without including this limit in our code at all, we allow for the redefinition of the limit, and increase the amount of situations that our code can be used for. Also, we did not include the amount of oil left for consumption, one trillion barrels, in our code at all because that number is purely theoretical and discrepancies between the true values exist (some venture to say that we have 2 trillion barrels, while others say we have 3 trillion). By not defining these values, we can run our code with whatever values we wish in mind.

Results

The normal curve produced by our model is controlled by two variables: The center (X_0), and sigma. (One variable essentially since sigma is defined by X_0) We began by entering a relatively large X_0 ($X_0 = 9$) hoping to see that a large majority of the impoverished people can be helped, without burning all the oil in the process. The data table that our code produced gives the desired graph (See Figure B-2), but our data table shows that 1.11 trillion barrels of oil were consumed in the 20 year period. This certainly does not meet our limit of 500 billion barrels, since we estimate that only 1 trillion are left for consumption. Thus, we had attained our first great achievement from our program, and we could conclude that: It was clear that oil is highly finite and the impoverished cannot be easily helped without major sacrifices from the rich countries. In summary, our first main achievement was using our program to show that the oil situation is severe and there is no easy solution because our supply of oil is too limited.

However, we did not lose hope. We set our X_0 lower and lower until we found that we can set X_0 at 2.8 (see figure B-3) and only consume 513 billion barrels of oil, which is approximately our limit. Yet, by looking at the graph, we can see that this is definitely not what we wanted to happen. This graph is produced because our bins are very large and X_0 is actually inside the first bin, causing people to move into it, but if we broke the graph down into smaller bins, we would see that progress in terms of resolving disparity was indeed made. However, since we wanted to stick to our 25 bin setting, we set X_0 to 2.9 (just barely inside the second bin). The program produces a highly desirable graph (Figure B-4), and according to our worksheet, we've consumed 600 billion barrels of oil. Although the limit was exceeded, we can take into account that 1 trillion is a conservative estimate, and more oil surely exists. As you can see from the figure, we've drastically changed the lives of billions of people (since oil consumption is correlated to GDP), while staying around our limit of 500 billion barrels. Approximately 1 billion people moved from the first bin into the second bin. If we speak of the bins in terms of wealth classes, the change is immense. Thus, we reached our second achievement from the program: We knew that although, there is little room for change, a significant amount of change can still be made; more precisely, we can make the world a much better place for 1/6 of the population, all we need now is the politics to do it, which no computer program could ever produce.

Having analyzed our future with the conservative figure of 1 trillion barrels, we decided to see what we could do if in fact, 3 trillion barrels of consumable oil were left, as many researchers suggest. The results were astonishing. Running the program for $X_0 = 12$ (inside the 5th bin), since we already knew the result for moving into the 4th bin, we got a beautiful graph (See Figure B-9), and our worksheet showed that 1.3 trillion barrels would be consumed in the process (less than half of the total oil available). That's right, over 7 billion people, nearly the entire population, can consume at least 11.4 barrels of oil per person per year. The U.S. currently consumes an unhealthy 24.7 barrels of oil per person per year. Thus, we came to our third and most important conclusion: It is possible to shift practically the entire population to consuming between 11.4 barrels/year/person and 14 barrels/year/person in 20 years, and in turn consume 1.3 trillion barrels.

Deeming this our most significant conclusion, the progression of the oil consumption vs. population situation is shown in Figure B-6 through B-9, for $X_0 = 12$.

Analysis and Conclusions

From running our code for several X_0's, we can conclude the following:

- If there are 1 trillion barrels of oil left for consumption:
  - The Oil Crisis is drastic, and no easy solution exists to either of our fundamental problems, because the supply of oil is too limited.
  - Yet, we can make a slight difference in the disparity amongst the world's people by enacting initiatives to reach the state in Figure B-4 in 20 year, and in turn, consume 600 billion barrels of oil.
- If there are 3 trillion barrels of oil left for consumption:
  - The Oil Crisis is actually a politic problem and the state visible in Figure B-9 can be achieved in 20 years, while consuming 1.3 trillion barrels in the process. Nearly the entire population of the globe can consume between 11.4 and 14 barrels of oil/year/person.
    - This is my far the most original and most significant achievement of our project. This finding is simply amazing, and is not cited, to our knowledge, anywhere else.

All three conclusions are major achievements. The first conclusion reemphasizes, in graphical form, the hype about the Oil Crisis and how the problem is utterly imminent and apparently unsolvable. Yet, our second conclusion shows otherwise. We can in fact drastically improve the lives of 1 billion people, that's 1/6 of the world's population. This conclusion shows that the disparity amongst people is not *entirely* a finiteness of oil problem, but also a lack of political initiative problem. Our most important conclusion, and thus our most original achievement, is definitely the third. From the data produced in our worksheet, we can see that the standard of living for more than 7 billion people can be increased, while in turn consuming 1.3 trillion barrels. Assuming that we have 3 trillion barrels of oil left, and that a technological breakthrough is coming in 2026 or soon thereafter that will provide an alternative energy source to replace oil, this finding is colossal. The U.S. consumes 24.7 barrels/year/person, an unhealthy level even for our standard of living many researchers suggest, so if we can have practically the entire world consuming at half the U.S.'s level, it would make a tremendous impact on the world.

Of course, these finding are not without err, since we've made many assumptions in our calculations, such as using averages. Also, although it's clear that the superior egalitarian state in Figure B-9 can be achieved, it's highly improbable that the world can produce that much oil over the 20 year period. Nonetheless, from our program, we know now that it is indeed possible to change the living standard of nearly everyone in the world, in terms of oil consumption. All that's left to do is get the politicians involved.

Future Work

Although our final conclusion is immense, there are many things we can do with our program to make it more realistic, and to display the results better. The first thing that we could do to enhance our program would be to do a substantial amount of research on each country that we're dealing with and stratify the population into consumption classes, this would allow for a more accurate result. Also, we could create dynamic bins, instead of the ones we have now. What this means is that the bins that contain a huge amount of people, would be broken down into smaller bins to show the distribution more specifically, however, this would have to occur after our shift to the egalitarian state, because it would be very difficult to define the values of the bin populations if the x-axis is not split into equal bins. The resulting equation would either be very complex, or non-existent, or we could make separate equations for the bins that get stratified. The next thing we could do, would be to take into account world wide oil production and its projected fluctuations, this would lead to the optimal X_0 for a given production projection, and a hypothesized amount of oil left for consumption.

Also, it would be interesting to try and use C++ to force Excel to make the graphs that we had to make manually. If we succeeded, the time used to view the results would be vastly decreased, and in turn, we would strengthen the user friendliness of our program.

All of these recommendations will surely be taken into account when working on next year's project, if we decide to augment this year's project.

Acknowledgements and Citations

We would like to take this time to thank our mentor and our teacher sponsor for the motivation and the logistics they provided for this project. They were the ones that kept us on course by helping us frequently and effectively. Dr. Storer helped us at the beginning of the project by helping us brainstorm the overall, theoretical concept of our project, he then referred us to Dr. Shashkov, who worked with us for the remainder of the project. He helped us by proof-reading the code and by checking the mathematics and logicality of our experiments. He also taught us various ways to approach the question when we encountered obstacles, which sometimes led to “Well let’s assume…” We would also like to extend our thanks to Mrs. Diane Medford, without whom, this project could have never began. We are extremely thankful that she took time out of schedule to be the Supercomputing Challenge sponsor for our school.

Citations

Books

Fine, Ben. The World of Consumption. 2nd ed. New York: Routledge, 2002

Savinar, Matthew D. The Oil Age is Over. San Francisco: Savinar Publishing, 2004.

Websites

Benett, Drake. Oil Futures. 26 February 2006. The Boston Globe. 04 Apr. 2006 <http://www.boston.com/news/globe/ideas/articles/2006/02/26/oil_futures/>.

Fisker, Jacob L. "One of the most important problems of the world." Oil depletion. 20 March 2006. 04 Apr. 2006 <http://quasar.unibas.ch/~fisker/401/oil/whoami.html>.

GeoDestinies. Myths and Realities of Mineral Resources. Youngquist, Walter Ph.D.. National Book Company. 1997. <http://dieoff.org/page132.htm>.

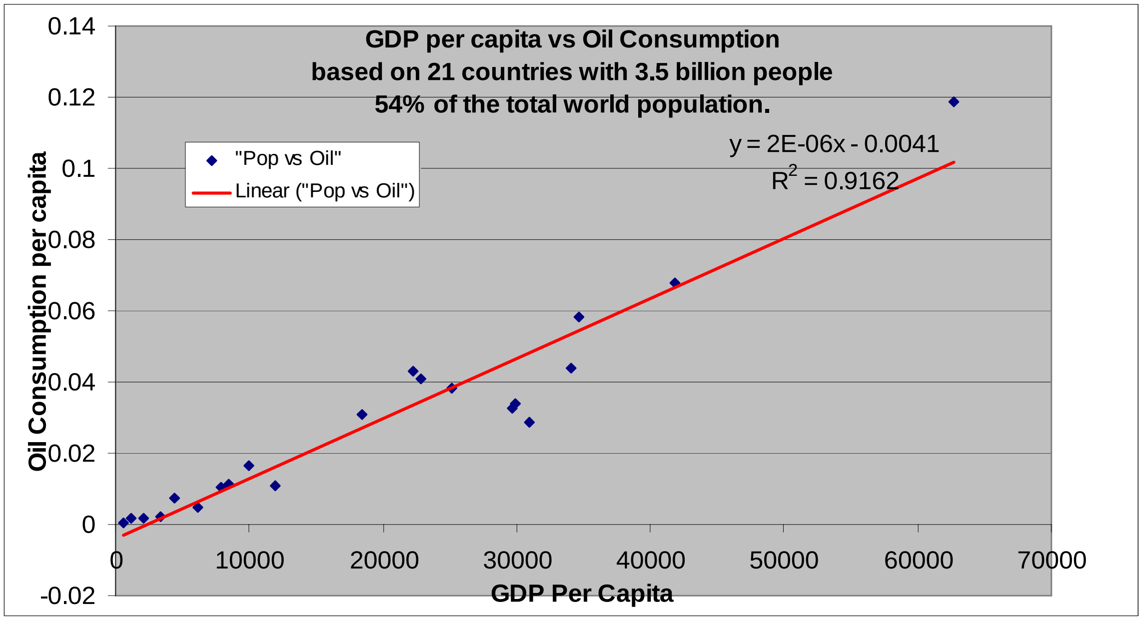
Gupta, A.K. "Third World Traveler." Oil: Reserves, Production, & Consumption. November 2002. Z Magazine. 04 Apr. 2006 <http://www.thirdworldtraveler.com/Oil_watch/Oil_ReservesProducConsump.html>.

"Rank Order, Oil Consumption." The World Factbook. 10 January 2004. CIA. 04 Apr. 2006 <http://www.cia.gov/cia/publications/factbook/rankorder/2174rank.html>.

Savinar, Matthew D. Life After the Oil Crash. 2004. Savinar Publishing. 04 Apr. 2006 <http://www.lifeaftertheoilcrash.net/SiteInformation.html>.

Appendix A: Graphs from our research

Figure A-1: A compilation of data from our research, showing that GDP is strongly correlated to Oil Consumption per capita.



Appendix B: Graphs from our code

Figure B-1: The current situation; 2006.

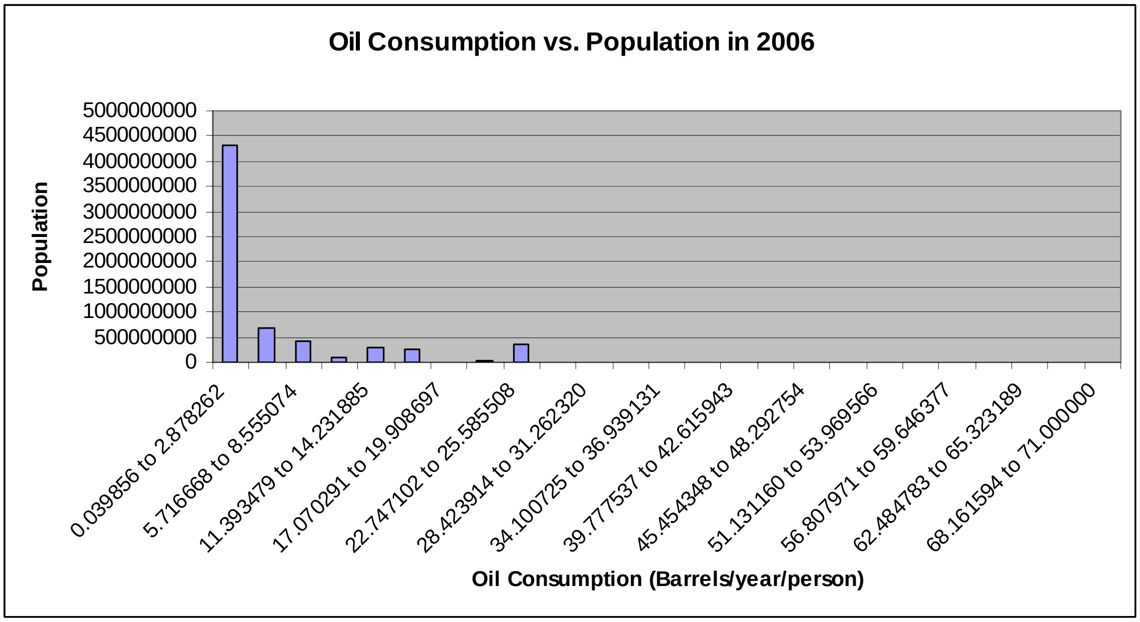


Figure B-2: The final situation if $X_0 = 9$.

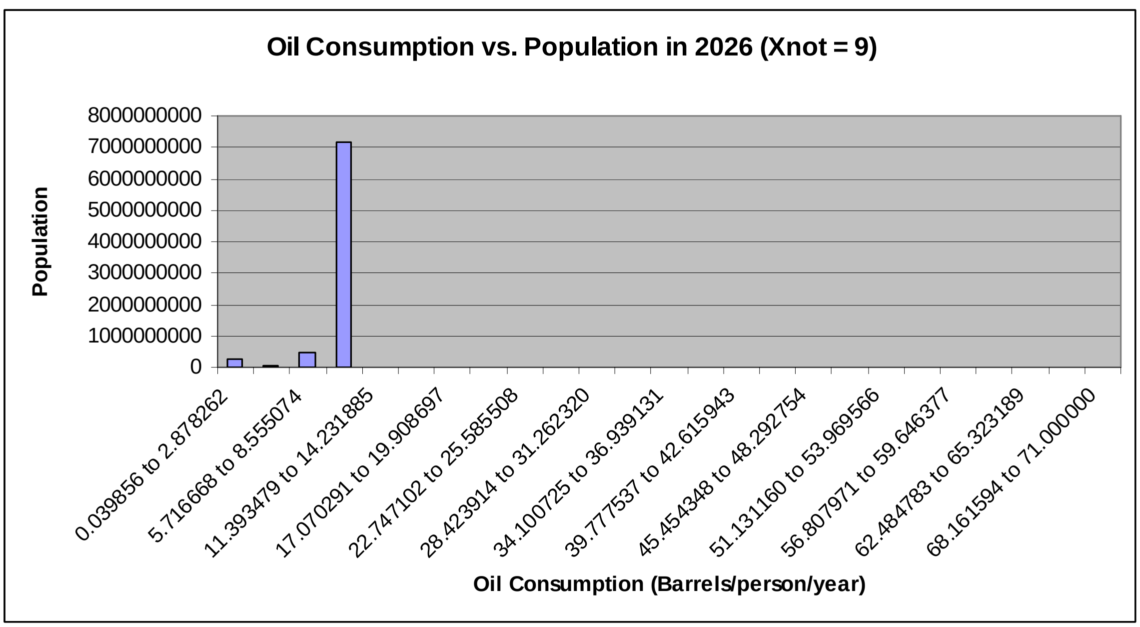


Figure B-3: The final situation if $X_0 = 2.8$.

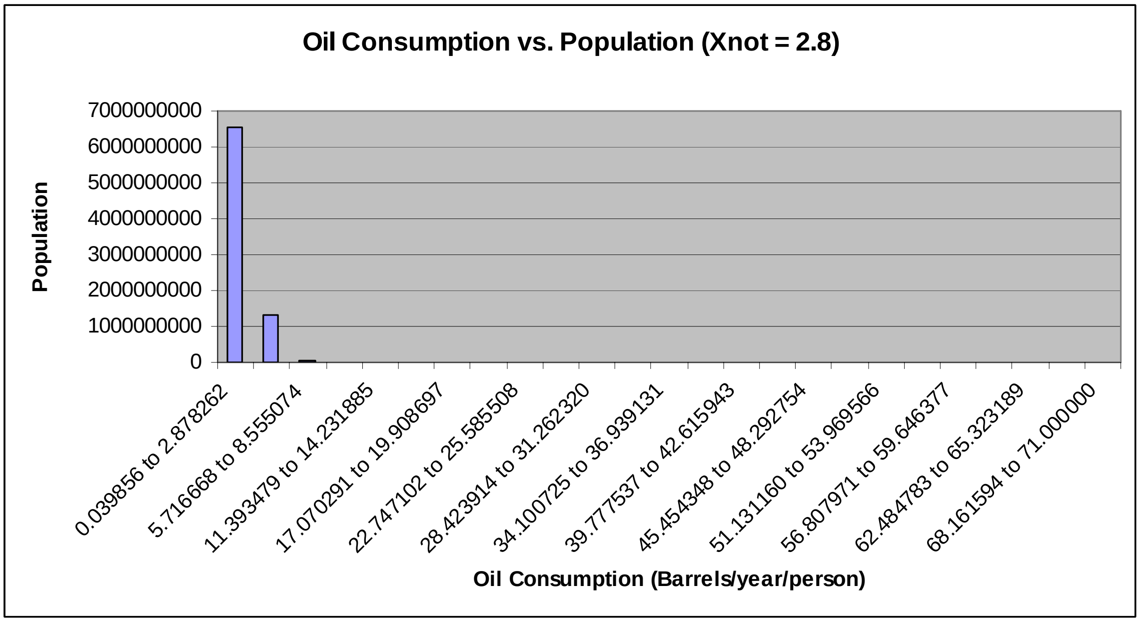


Figure B-4: The final situation if $X_0 = 2.9$.

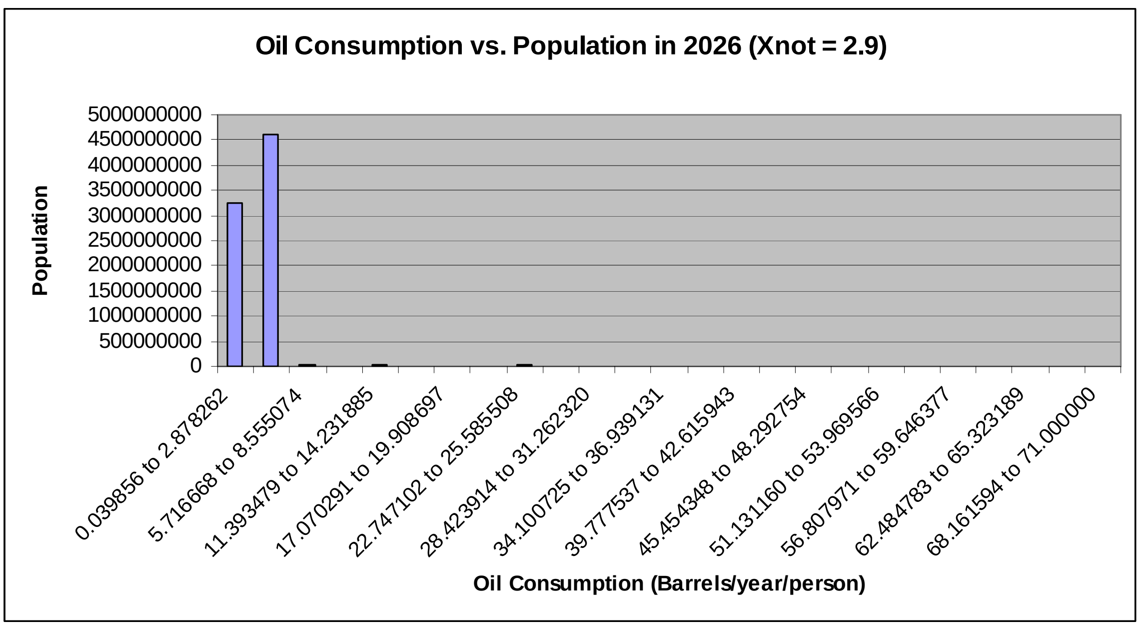


Figure B-5: The situation in 2006(shown again, to see progression easier).

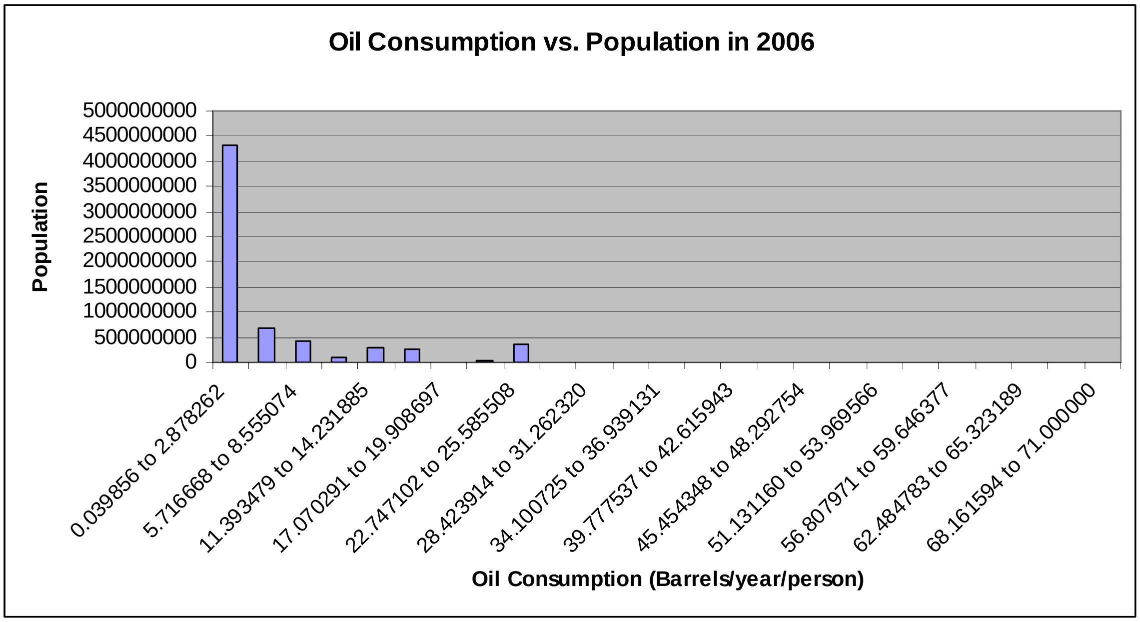


Figure B-6: The situation in 2011 if $X_0 = 12$.

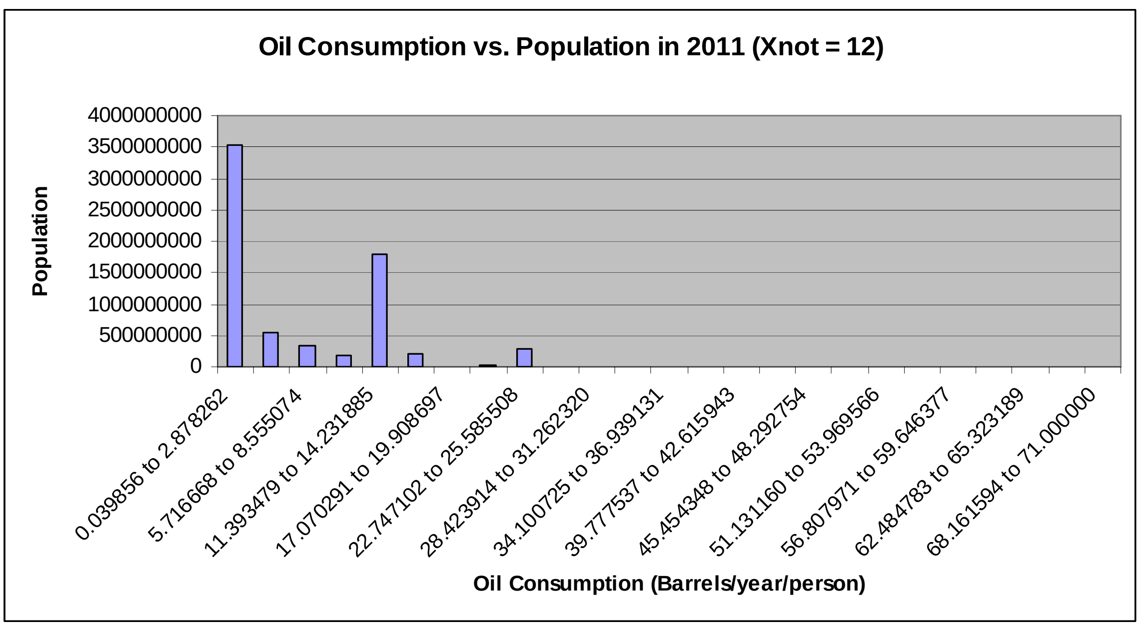


Figure B-7: The situation in 2016 if $X_0 = 12$.

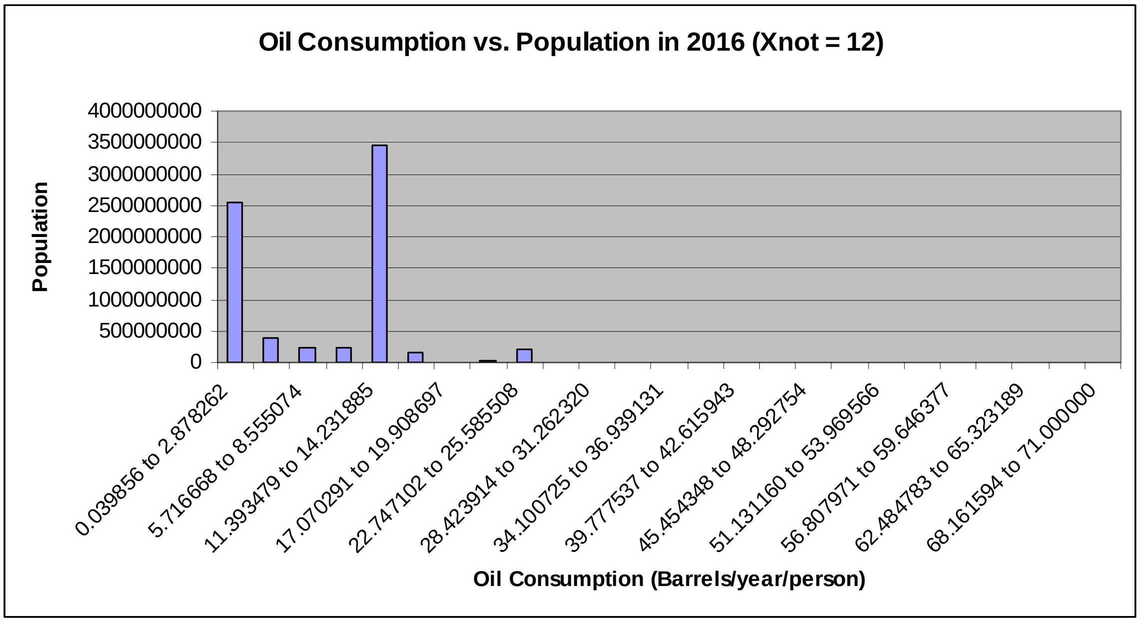


Figure B-8: The situation in 2021 if $X_0 = 12$.

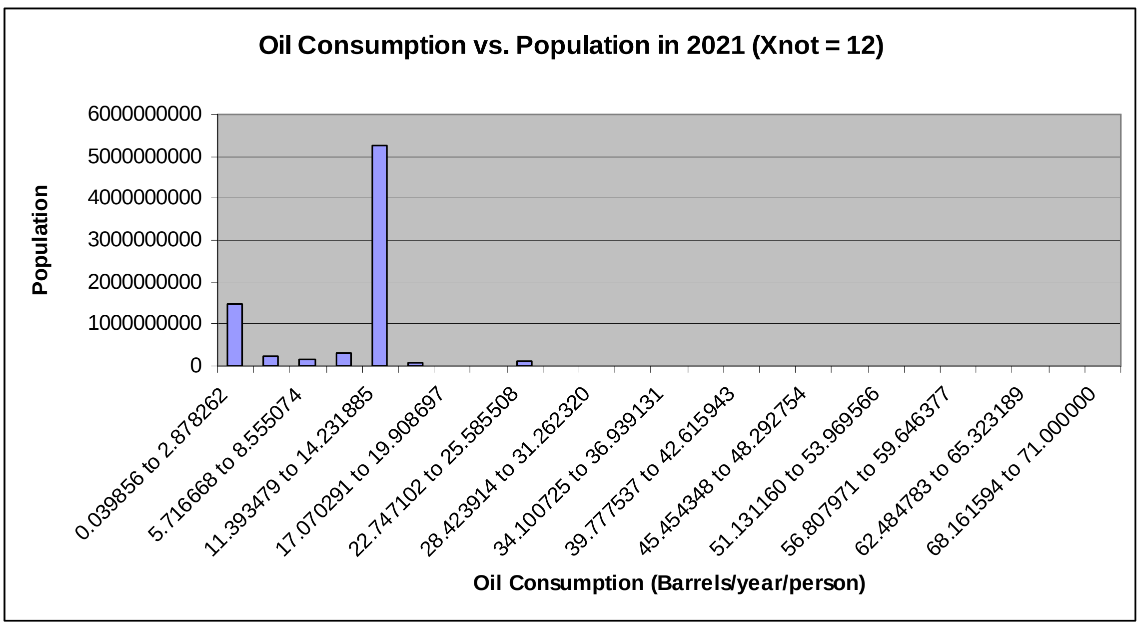
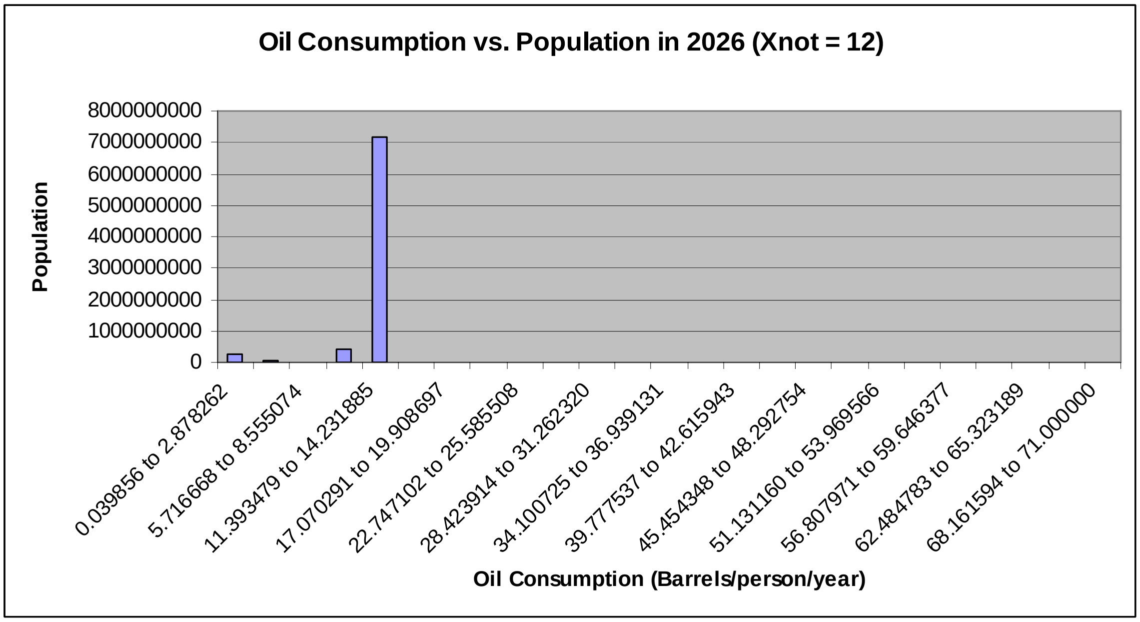


Figure B-9: The final situation if $X_0 = 12$.



Appendix C: Code

```
/*

	Modeling the Future of Oil Consumption and the Feasibility of
	What We Can Do To Help
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	Team #048
	Los Alamos High School
	AiS 2005-2006
*/

//General Inherency of Essential Classes
#include <string>
#include <fstream>
#include <vector>
#include <stdio.h>
#include <iostream>
#include <math.h>
using namespace std;

//Define the variables essential to our model
double Xnot = 0; //Initialize the center of our normal curve
double sigma = 0;//the standard deviation of our normal curve
int n = 0; //beginning year: 2006
double N = 21; //end year :2026
int m = 25; //the number of intervals in our x-axis

void main()
{
	//The very first thing we need to do is to get the desired Xnot
	from the user
	cout << "Enter a desired Xnot to fit a normal curve around: ";
	cin >> Xnot;
	//Now we define sigma as 10% of Xnot to allow for some disparity
	amongst the people
	sigma = .1 * Xnot;

	//*******READ IN CONSUMPTIONS**************
	vector<string> consump_file;
	int nC = 211; //The number of countries we want to read from list
	(This is present for debugging purposes
	double consump[211];
	ifstream ifs( "consumptions.txt" ); //Open the file containing
	consumption info.
	string temp;

	while( getline( ifs, temp ) ) // Go through each line and read
	the data into the vector
	consump_file.push_back( temp );

	for(int i = 0; i < nC; i++)
	{
	// We need to cast the data to double, via the atof() function,
	so we can use it. Also, make the unit barrels/year by multiplying
	by 365.
```

```
		consump[i] = atof(consump_file[i].c_str()) * 365 ;
	}
	//*********************************************

	//********READ IN POPULATION******************
	vector<string> pop_file;
	double pop[211];
	ifstream ifss( "populations.txt" );
	string temp2;

	while( getline( ifss, temp2 ) )
		pop_file.push_back( temp2 );

	for(int j = 0; j < nC; j++)
	{
		pop[j] = atof(pop_file[j].c_str());
	}
	//*********************************************

	//*************DEVELOP STATUS QUO DATA*************
	double Xmin = 10^12, Xmax = -1; //Define Xmin and Xmax to store the smallest and largest oil consumption per capitas per year for each country
	double Xleft[25], Xright[25]; //These serve to define the bins that we are about to break our X-axis into, so that we can have a histogram of sorts.
	double popBin[25]; //the population in each bin

	for (int h = 0; h < nC;h++) //Cycle through the the countries and calculate consumption per capita per year.
	{
		double CpC = consump[h] / pop[h]; //CpC = Consumption per Capita
		if(Xmin > CpC)
			Xmin = CpC; //Stick the lowest consumption in Xmin
		if(Xmax < CpC)
			Xmax = CpC; //Stick the largest consumption in Xmax
	}

	Xmin = Xmin - .01; //Offset Xmin by a miniscule amount so the bins can be added to.
	/*
	When we originally ran the program, the graph that was produces had nearly everyone in the first bin.
	This was due to the presence of outliers, since some countries have very large consumptions, and a small
	population.  We decided to throw out these countries by setting Xmax.  We removed around 360,000 people
	in the process, which is a miniscule amount in relation to the problem we are trying to solve.
	*/
	Xmax = 71;

	for (int u = 0; u < m; u++) // Cycle through our bins; m = 25;
	{
		// Define Xleft
		Xleft[u]= Xmin + (((float)u / (float)m) * (Xmax-Xmin));
```

```
		Xright[u] = Xleft[u] + (((float)1/(float)m) * (Xmax-Xmin));
		// and Xright to define the bin.
	}

	for (int y = 0; y < m; y++) // Cycle through our bins
	{
		popBin[y] = 0; // Initialize the population of each bin
		for(int q =0; q< nC; q++)//Go through each country to see
		if it fits in this bin
		{
			double CpC = consump[q] / pop[q];
			if ((CpC > Xleft[y]) && (CpC <= Xright[y])) // If it
			does...
			{
				popBin[y] = popBin[y] + pop[q]; //Add the
				population of that country to the population of
				this bin.
			}
		}
	}

	//*********SEND STAT QUO DATA TO EXCEL***********
	FILE *statQuo;
	statQuo = fopen("StatQuo.xls", "w"); //Open file in write mode
	for(int t=0; t < m;t++) //Cycle through each bin
	{
		fprintf(statQuo, "%f", Xleft[t]);
		fprintf(statQuo, " to ");
		fprintf(statQuo, "%f", Xright[t]);
		fprintf(statQuo, "\t");
		fprintf(statQuo, "%f",popBin[t]);
		fprintf(statQuo, "\n");
	}
	fclose(statQuo);
	//***********************************************

	//********PREPARE EQUATION COMPONENTS************
	double Xi[25]; //An array of the centers of our bins;
	//The equation that our model employs to shift to the normal
	curve requires several
	//components.  They are defined in this segment of code.
	double sumE = 0; //Initialize the variable we will use to
	normalize our end population proportion
	double totalPop = 0; //Initialize the variable we will use to
	store the total population we are going to deal with.
	double pHat0[25]; //Make an array of the initial population
	proportions for each bin;
	double pHatN[25]; //Make an array of the end population

	for(int w =0; w < m; w++) // Cycle through each bin
	{
		Xi[w] = 0; // Initialize the center to 0
		Xi[w] = (Xright[w] + Xleft[w]) / 2; //Define the center of
		our bin
```

```
        totalPop = totalPop + popBin[w]; //Define the total
        population we are dealing with by adding the populations of
        all the bins.

        sumE = sumE + (exp(-1 * pow((Xi[w] - Xnot), 2) / sigma));
}
//Now that we have totalPop that we're dealing with, and sumE(a
constant) let's define the two key componenets of our equation
for(int g = 0; g < m; g++)//Cycle through the bins...
{
        pHatN[g] = exp(-(pow((Xi[g] - Xnot),2) / sigma)) /
        sumE;//...and define the end population proportion...
        pHat0[g] = popBin[g] / totalPop; //...and define the
        initial population proption for each bin.
}
//************************************************

//*******GENERATE GRAPH FOR A SPECIFIC YEAR******

//Define the 2-dimensional array that we are using the store the
new populations of each bin. First bracket is for each year, and
second bracket is for each bin;
double popBinNew[21][25];
double totalConsumed = 0; //Initialize the variable we are going
to use to represent the total amount of oil consumed in this 20
year period.

/*
To make our model more feasible, we factored in the estimated
population of the world
for each year that our model iterates through.  For increased
accuracy, we used definitive numbers that were a result of
serious study, instead of using a generic equation.
*/
double totalPopAtYear_n[21]; //This variable will store all the
projected world populations
totalPopAtYear_n[0] = 6525486603; //Pop of the world in 2006
totalPopAtYear_n[1] = 6600115810;
totalPopAtYear_n[2] = 6675056342;
totalPopAtYear_n[3] = 6750284385;
totalPopAtYear_n[4] = 6825750456;
totalPopAtYear_n[5] = 6901439322;
totalPopAtYear_n[6] = 6977242285;
totalPopAtYear_n[7] = 7052858248;
totalPopAtYear_n[8] = 7128025638;
totalPopAtYear_n[9] = 7202516136;
totalPopAtYear_n[10] = 7276282928;
totalPopAtYear_n[11] = 7349338533;
totalPopAtYear_n[12] = 7421568786;
totalPopAtYear_n[13] = 7492858409;
totalPopAtYear_n[14] = 7563094182;
totalPopAtYear_n[15] = 7632275013;
totalPopAtYear_n[16] = 7700419366;
totalPopAtYear_n[17] = 7767447616;
totalPopAtYear_n[18] = 7833310135;
totalPopAtYear_n[19] = 7897989420;
totalPopAtYear_n[20] = 7961586278; //Pop of the world at 2026
```

```
        FILE *Results;
        Results = fopen("Results.xls", "w"); //Open the file that will
        store our end product(A formatted worksheet)
        fprintf(Results, "Xnot:\t%f", Xnot);
        fprintf(Results, "\n");
        fprintf(Results, "Sigma:\t%f\n\n", sigma);
        for(int f = 0; f < N; f++) //Cycle through each year
        {
              for(int r = 0; r < m; r++) // Cycle through each bin
              {
                    popBinNew[f][r] = 0; //Initialize the new population
                    of the bin to 0
                    /*
                    Here we have our main equation (for an easier to read
                    version, see our report). The following line of code
                    fills an array with the population of each bin as we
                    fuse the initial population proportion situation,
                    pHat0[], with what we want the population proportion
                    for each bin to be, pHatN[], over N years in
                    increments of n.
                    */
                    popBinNew[f][r] = totalPopAtYear_n[f] * ((pHat0[r] *
                    (1 - ((double)f/N))) + (pHatN[r] * ((double)f/N)));
                    /*
                    Also in this loop, we calculate the amount of oil
                    we're going to consume in this 20 year period.
                    Although, we are using Xi, the center of the bin,
                    instead of the actual consumptions, the result
                    should be the practically the same.
                    */
                    totalConsumed = totalConsumed + (Xi[r] *
                    popBinNew[f][r]);
              }
              //All that's left to do is send the information to an Excel
              file in a nice, clean format
              fprintf(Results, "Year %i:\t\n ", 2006 + f);//Designate the
              year to which the information pertains
              for(int s=0; s < m;s++)//Cycle through each bin
              {
                    fprintf(Results, "%f", Xleft[s]);
                    fprintf(Results, " to ");
                    fprintf(Results, "%f", Xright[s]);
                    fprintf(Results, "\t");
                    fprintf(Results, "%f",popBinNew[f][s]);
                    fprintf(Results, "\n");
              }
              fprintf(Results, "\n");
        }
        //Also, add the total amount of oil consumed in this period to
        the worksheet..
        fprintf(Results,"Total Consumed:\t");
        fprintf(Results,"%f", totalConsumed);
        fclose(Results); //Stop streaming with the file, close, and end.
        //All that's left at this point is to open the Results.xls file
        and see if the goal was accomplished!
        cout << "Success.\n";
}
```