In this paper, a model was developed to calculate the relative costs to sequester various amounts carbon dioxide annually and the amounts of carbon dioxide emitted that could be sequestered within a given period of time. The first part of the model calculates the cost to sequester a given amount of carbon dioxide using saline formation sequestration, ocean sequestration, or any combination of the two. The second part of the model uses the average growth of power generation from renewable sources to predict carbon levels; since carbon emissions are capped at a certain level, the growth of power generation from non-emitting, renewable sources would decrease the need of carbon-emitting sources to produce electricity. We find that, if the energy market is let to run naturally, by 2087 the power generating sources would not emit any carbon. Although weaknesses exist in this model, it is fundamentally robust because combined the two parts can predict what we should do in order to achieve national carbon neutrality from power generating sources with minimal cultural and economic impact. From our model we concluded that the United States should spend $52 billion for five years to set up a system for carbon sequestration, and then spend approximately $94 billion per year to cut emissions by 657 million metric tons of carbon dioxide per year, achieving carbon neutrality from power generating sources in 2077.

Introduction

Environmental issues have moved to the top of the priority lists of many governments and citizens. We hear various reports, some predicting a world spiraling out of control due because of global warming if we go beyond 450 parts per million (ppm) of greenhouse gases; currently, we are at 370 ppm. However, despite the debate surrounding the possible effects of global warming, the international consensus has been that the amount of carbon dioxide emitted by mankind has drastically increased and that has tempered with the state of the environment in an unnatural way. As the world's second largest contributor of greenhouse gases, the United States emits around 22% of the world's carbon dioxide. Thus, solutions around the world, and solutions within the United States, have been drawn up to limit mankind's emission of carbon. One strategy would be carbon sequestration.

Carbon sequestration relies on knowledge of the earth's natural carbon cycle. The carbon cycle has three major depositories. The largest are the oceans, which can store approximately $38{,}000*10^{15}$g of carbon, next is the earth, where approximately $2{,}000*10^{15}$g of carbon can be stored, and the smallest is the atmosphere, where approximately $730*10^{15}$g of carbon can be stored. As the world has become more industrialized it has become reliant on carbon based fuels take from the earth. Now power plants, factories, and cars emit carbon dioxide, the product of the combustion of coal and oil. The carbon dioxide is released into the atmosphere, which is the smallest depository for holding carbon. This causes an imbalance in the earth's carbon cycle in that we are putting the carbon that was stored in the earth and releasing it into the atmosphere. Carbon sequestration works by taking in carbon from the atmosphere and placing it into the earth or in the ocean, which can naturally hold a significant amount of carbon. There are two major types of sequestration considered in this model: the injection into deep saline formations underground and the injection into trenches at the bottom of the ocean. Both are considered to be unlimited as to how much CO_2 they can hold, based on the enormous ratio of capacity of each to the amount of carbon dioxide that can be produced in the United States over a long period of time. Both methods can only sequester the carbon that is emitted from point-sources, such as the power and industrial sector, as it is impossible to capture carbon that is emitted from every home and every automobile, especially because the later moves.

Another way of reducing the amount of carbon that is emitted is decreasing the dependence on nonrenewable sources for power generation. Many renewable resources emit a negligible amount of carbon dioxide when they produce energy. Current trends of renewable resources show that they amount of energy generated are increasing, which gives these resources potential to replace nonrenewable resources in terms of providing the same amount of power.

Combining these two approaches into one system would allow for a model to be made that could project the possibility of a carbon neutral future.

Assumptions:

- Carbon dioxide will be capped at emissions levels from 2007: 3,354,000,000 metric tons.
- All sequestration stations of the same variety (geological, ocean) sequester equal amounts of CO_2 in equal time.
- Sequestration can only start after the entire sequestration system is established.
- The amount of space available in the ocean for potential CO_2 sequestration is unlimited.
- The amount of space available in deep saline sequestration is unlimited.
- The network of U.S. natural gas pipelines can be extrapolated to be comparable to the price, building time, and necessary locations for a system of CO_2 transportation pipes.

- Energy demand levels will remain at 2007-2008 levels because CO_2 emission is capped at those levels.
- The total amount of energy consumed in the U.S. was the total amount of energy generated.
- Renewable resources – nuclear, conventional hydroelectric, wood, waste, geothermal, solar/PV3, and wind – do not emit any carbon dioxide.
- Nonrenewable resources – coal, petroleum, and natural gas – are all assumed to produce equal amounts of carbon dioxide when burned.

The Model Part I

Variables:

I = initial cost of construction

C_t = total cost of all sequestration in year t, where t is in years from 2007, and $t \geq t_s$ where t_s is the time it takes to complete construction

C_y = the cost to sequester for one year y after all initial costs have been paid

P_s = metric tons per year sequestered using saline injection

P_o = metric tons per year sequestered using deep ocean injection

S_y = the amount of CO_2 sequestered in one year y.

D = total distance of pipes in kilometers necessary to connect point sources to injections sites

Constants:

C_s = cost per metric ton of saline formation injection

C_o = cost per metric ton of deep ocean injection

C_c = cost per metric ton of carbon capture from industrial flue gases

C_p = cost per kilometer of pipe

C_{main} = cost of maintenance per kilometer of pipe

K_p = the rate of pipeline construction

To Calculate C_y, the cost to sequester without any initial costs for one year y, where y is the number of years since 2008, and $y \geq t_s$ because during the construction interval no CO_2 will be flowing, we will need to sum the cost of carbon capture and the cost of injection for that year. We have the costs of injection per metric ton for each process, so to find the cost per year of each one we multiply by the metric tons of CO_2 that will be processed by each method in that year. We also have the cost of capture of CO_2 per metric ton, so we multiply that by sum of the metric tons per year for each sequestration method. Finally, we have the cost of maintenance of one kilometer of pipe, which we then multiply by the total distance of pipes. This yields:

$$C_y = (P_s C_s + P_o C_o + (P_s + P_o) * C_c + C_{main} * D) \quad \text{(Eq. 1.1)}$$

In this equation, the total carbon dioxide sequestered in that year, S_y, is equal to the sum of all of the sequestration done by each method. That is:

$$S_y = P_s + P_o \quad \text{(Eq. 1.2)}$$

To calculate C_t we sum all C_y and add on I, the initial startup cost.

$$C_t = I + \sum_{t_s}^{t} C_y \quad \text{(Eq. 1.3)}$$

We must next look at I, the initial start up cost. This cost comes from the construction of a network of pipes that would be necessary for the transport of CO_2. We do not count the cost of the construction of the injection sites into I because the maintenance and construction of the injection sites has already been factored into the cost per metric ton. So:

$$I = D * C_p \tag{Eq. 1.4}$$

We finally need to calculate t_s, the time it takes for construction. Here we assume that the construction of the pipeline network is the limiting factor in construction. We assume this because of the sheer number of pipelines that need to be constructed. The limited number of companies who can construct these pipelines should make their construction take longer than any of the sequestration sites. So:

$$t_s = \frac{D}{K_p} \tag{Eq. 1.5}$$

Sequestration relies on capturing the CO_2 at point sources such as factories and shipping it to injection sites. Thus, all emissions cannot be sequestered, because emissions cannot be captured and shipped from moving sources such as automobiles. But $3.701*10^9$ metric tons of CO_2 come from point sources such as factories and power plants. So we can use our model to try and calculate the total cost to sequester all of these emissions from point sources.

We need to find a way to estimate the total kilometers of pipeline necessary to connect all of the point sources to injection sites. To get an idea of how many kilometers this would be we look at the already existing system of natural gas pipelines. There are 486,000 kilometers of natural gas pipelines in the United States, and these pipelines connect or are close to all major industrial areas and power centers. So we can use this distance of pipe to estimate the time of construction and the initial cost of construction. We start with the cost of building such a pipe system. A study at MIT estimated that laying one mile of pipeline would cost $800,000. This price was subject to fluctuation depending on the location, but because this construction would be on such a large scale the net price should average out to the given $800,000 per mile. $800,000 per mile is equal to $496,000 per kilometer. So using Eq. 1.4:

$$I = D * C_p$$
$$I = 486{,}000 * 496{,}000$$
$$I = 241{,}000{,}000{,}000$$

So the initial cost would be $241 billion dollars.

Next we determine t_s. We return again to the already existing natural gas pipelines. In this network there are 210 different systems. So we will suppose that in our new network there are also 210 systems, and that each has a roughly equal amount of pipeline to be constructed. Each system would be given out to a separate contractor. To find out the time it takes to build a kilometer of pipeline we looked at a pipeline project in Azerbaijan, where one company built 505.14 kilometers of pipeline in one year. So the rate of construction will be equal to the number of contractors multiplied by 505.14 kilometers per year. So using Eq. 1.5:

$$t_s = \frac{D}{K_p}$$
$$t_s = \frac{486{,}000}{505.14 * 210}$$
$$t_s = 4.58$$

So it would take 210 contractors approximately 4.58 years to construct the necessary pipeline system. The total cost would come out to $52.62 billion per year.

Next we calculate the cost of sequestration for one year. A Department of Energy survey estimated that they could sequester $1.82 * 10^8$ metric tons of CO_2 for $212,400,000. This comes out to $1.17 per metric ton. Another Department of Energy sponsored project estimated that it could sequester $1.00 * 10^6$ metric tons for $4,425,178. This comes out to $4.23 dollars per metric ton. The estimate for the upkeep of pipeline was $3189 per kilometer; this is expensive because extensive measures have to be taken to prevent leaks and the system is constantly under high pressure, so frequent repairs are necessary. The estimate for the capture of carbon was $136.5

per metric ton of carbon captured from flue gas. Suppose that we want to sequester all CO_2 emissions in some year *y*. To do this we need to know what the total emissions will be in that year. We have developed a second model to predict CO_2 emissions in the years following 2008.

The Model Part II

Variables:

G_{NR} – megawatts of power generated from nonrenewable sources

G_R – megawatts of power generated from renewable sources

G_{WO} – megawatts of power generated from wood sources
G_{WA} – megawatts of power generated from waste sources

G_G – megawatts of power generated from geothermal sources

G_S – megawatts of power generated from solar sources

G_W – megawatts of power generated from wind sources

G_N – megawatts of power generated from nuclear sources

G_{HC} – megawatts of power generated from hydroelectric sources

Constants:

G_{total} – 4,159,514MW of energy per year (at the end of 2007)

E_{cap} – 3,354,000,000 metric tons of carbon dioxide emitted in 2007

CF – CF = 113.67 metric tons of carbon per megawatt

Since we have assumed that no one will emit more than the carbon levels at 2008 because they have been capped at those levels, we can also assume that the total energy demand will equal that of year 2008. Looking into the Energy Information Administration database, we find that the United States has generated 4,159,514MW of energy (G_{total}). In order to make the model run more smoothly, we have assumed that the United States will also be consuming only 4,159,514MW each year.

Thus, every year, the energy sources – nonrenewable and renewable – need to satisfy 4,159,514 megawatts of energy. At the end of 2007, energy generated from "nonrenewable sources" are 2,963,739MW (this is G_{NR}). This means that renewable sources provide 1,195,775MW (this is G_R). Using data from the Energy Information Administration database, we find that there has been 3,354,000,000 metric tons of carbon dioxide emitted in 2007; this is our cap of carbon dioxide released and represented by E_{cap}. We can create a Carbon Factor (CF), and this will stand for the amount of carbon, in tons, produced per megawatt generated.

$$E_{cap} / G_{NR} = CF \qquad \text{(Eq. 2.1)}$$

The standard CF that is used will be from 2007.

3,354,000,000 / 2,963,739 = 1131.67 tons of carbon per megawatt

Thus

CF = 113.67

However, since we assume that renewable sources do not emit carbon dioxide:

$$(G_{NR})(CF) = E_{cap} \qquad \text{(Eq. 2.2)}$$

We find the emission total (E_{cap}) is 3,354,000,000 metric tons of carbon dioxide per year. Since the amount of carbon dioxide is capped at the 2007-2008 level, carbon emitting sources do not generate more electricity since they cannot emit more carbon. On the other hand, renewable sources of power will most likely expand since they do not produce carbon dioxide. Since the desire is to decrease the amount of carbon that we emit each year, we are assuming that power generated from renewable sources will begin to replace the power generated from nonrenewable resources. However, can the power generated from renewable sources totally replace the power generated from nonrenewable sources so that the amount of carbon dioxide emitted each year will be zero?

In order to find this, we need to find how fast renewable resources are expanding. Using Excel, we find the trend of the growth for the past 14 years in terms of electrical generation from alternative sources:

Figure 1

Renewable Sources	**Equation of power generation**
Wood	$G_{WO}(x) = 133.3604396(x)-229359.3451$
Waste	$G_{WA}(x) = -512.386813(x)+1043578.391$
Geothermal	$G_{G}(x) =10.68956(x^2)-42758.39(x)+42772888.4$
Solar	$G_{S}(x)=6.081318681(x)-11638.75$
Wind	$G_{W}(x)=277.8626374(x^2)-1109755.984(x)+1108066357$
Nuclear	$G_{N}(x)=13440.91648(x)-26156417.21$
Hydroelectric Conventional	$G_{HC}(x)=-4748.8857(x)+9787746.657$

These equations were created from the data that was provided by the Energy Information Administration database. The data was the megawatts of power that each source of renewable power produced within each year. We felt that the increase or decrease of the amount of power produced from these renewable sources incorporated the cost and feasibility of expanding these forms of alternative energy. Thus, these equations were used to project how many megawatts of power could be generated from each source of renewable alternative energy resource.

Again, we know that 3,354,000,000 metric tons of carbon dioxide are annually put out – that is from the 2,963,739MW generated from nonrenewable sources. Using the equations that we have found for the generation of energy (in megawatts) from renewable sources, it is possible to find when the emission of carbon emitted from power generating sources is equal to zero.

$G_{total} = G_{NR} + G_R$

where $G_R = G_{WO}(x) + G_{WA}(x) + G_G(x) + G_S(x) + G_W(x) + G_N(x) + G_{HC}(x)$

In order to find how the carbon dioxide output is decrease as the amount of energy generated from nonrenewable sources decrease, we use Eq. 2.2 and we can use the total generation of energy equation to find that:

$$G_{NR} = G_{total} - G_R \quad \text{(Eq. 2.3)}$$

Therefore, we can calculate how the emission decreases as generation of power from renewable resources increases through:

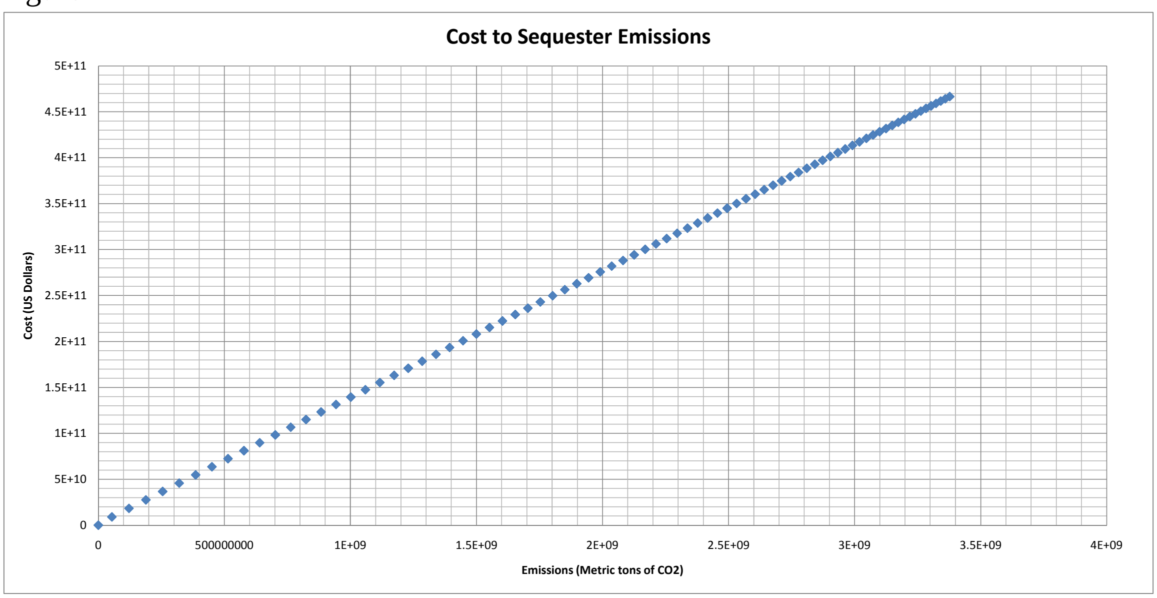
$$E_{total} = (G_{total} - G_R)(CF) \quad \text{(Eq. 2.4)}$$

Inserting this equation into the Excel spreadsheet, we find that 2087 would be the first year where there is no carbon dioxide emitted from power sources; this means that power from nonrenewable sources will no longer be used. (please refer to table 1 in appendix)

With the data generated from the second part of the model we can use Eq. 1.1 to calculate the cost to sequester all point source carbon emissions in any year after 2008. We will use only ocean sequestration, because it is the cheapest method. In the first five years the cost would be

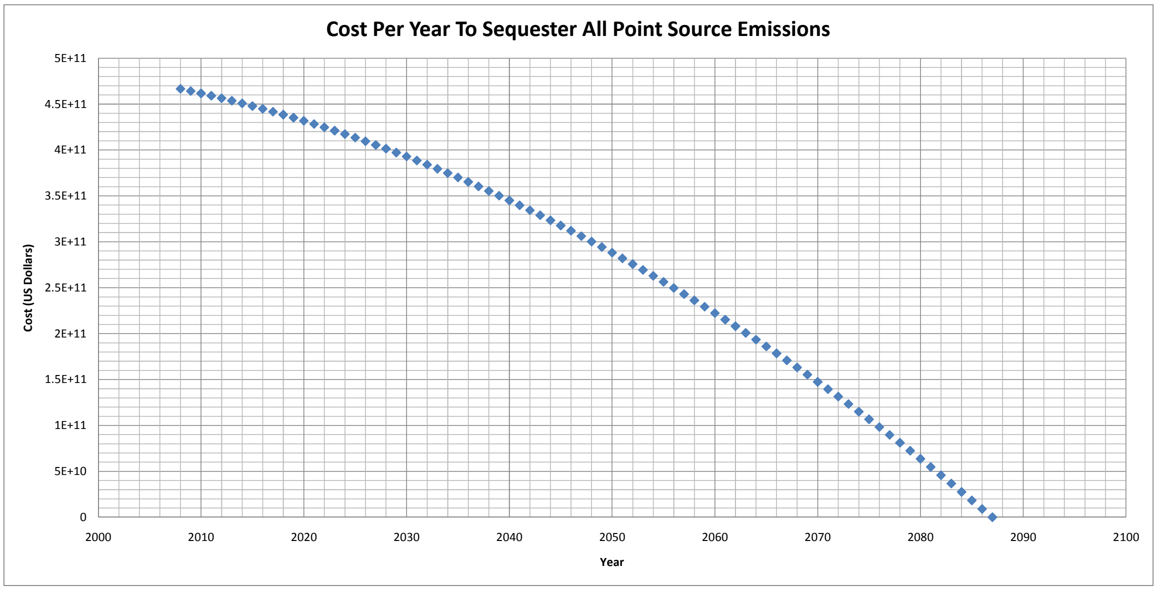
$52.62 billion per year, because that is the construction period. Starting in year 2013 our model predicts that the total amount of point source emissions will be 3.283 billion tons of CO_2. The cost to sequester all these emissions would be 453.6 billion dollars. This cost would go down each year until 2087 when it would equal zero because the pipelines could be shut down. The costs to eliminate a certain amount of emissions are shown in Figure 2, and the cost per year until 2087 is shown in Figure 3.

Figure 2



Refer to the Appendix for a larger version (Graph 1)

Figure 3



Refer to the Appendix for a larger version (Graph 2)

Using Eq. 1.3 we can calculate the total cost to sequester all point source emissions until they cease. This total cost comes out to 22.58 trillion dollars. From this cost we can see that it is infeasible to sequester all emissions from point sources, that is we cannot afford to be carbon neutral from 2013 until 2087.

However, say that we wanted to spend only a set amount of money each year to sequester CO_2 point emissions. Say we set aside a maximum of 50 billion dollars per year to sequester carbon emissions. Using Eq. 1.1 we find that if we spent 48.04 billion dollars and used only ocean sequestration we could eliminate 317.3 million metric tons of CO_2, or 10% of 2013's total point emissions. We could do the same thing for 49.07 billion if we used only deep saline formation sequestration. We can extend this to other values, outlined in the table below:

Table 1

	Saline Sequestration		Ocean Sequestration	
% Sequestered	Cost Per Year (in billions of dollars)	Year Neutral	Cost Per Year (in billions of dollars)	Year Neutral
5	24.65	2085	24.15	2085
10	47.76	2082	46.75	2082
15	70.86	2080	69.35	2080
20	93.96	2077	91.95	2077
30	140.2	2072	137.2	2072
40	186.4	2066	182.4	2066
50	232.6	2060	227.6	2060
100	463.6	2013	453.6	2013

Strengths:

Our model can predict the cost of sequestration for any amount of CO_2 that needed to be sequestered in the United States. It can also predict how much CO_2 could be sequestered each year using a set amount of money. Its versatility allows us to evaluate many options and then choose the best one.

Our model allows for a choice between two types of sequestration, ocean sequestration and deep saline sequestration. In the model any combination of the two can be used, so it is possible to find a medium between the risks associated with each method and the costs of each method.

Our model also accounts for the natural decrease in point source emissions due to economic development. It allows us to project what power plant and industrial emissions will be in a given year, so that we can pinpoint the year that the United States will achieve carbon neutrality given a certain percentage of emission reductions.

Weaknesses:

There are several weaknesses to this model. First of all, this model only takes into account the industrial and electrical sectors. It does not cover the commercial, residential, and transportation sectors. But, most of the CO_2 emission in residential and commercial sectors come from the electrical sectors, and thusly would be made better either way. But, transportation is still unaccounted for, and that supplies the second highest amount of CO_2 emission.

Another weakness comes from the assumption that petroleum, natural gas, and coal all produce the same amount of CO_2. In reality, natural gas produces 30% less carbon dioxide that petroleum and 45% less carbon dioxide than coal. So, our model fails to account for the reduction in emissions that may come by increasing the use of natural gas instead of coal and petroleum.

A third weakness comes from the fact that the reductions part of our model doesn't cover the short term reductions that may come from improving fossil fuel emission rates. Increased use of clean coal and natural gas can cut down CO_2 emissions in the short term from the electrical and industrial sectors, but it ends up being overly complicated to compute the rates at which the US should switch to these and at what added time and price.

A final weakness was that the equations used for estimating the growth of power generation by renewable sources had an r^2 value of less than .9%. What this means is that the trends for the equations did not fit the data as well as they could have. So, there was some degree of error in the amount of growth of renewable energy.

Conclusion:

The purpose of this model was to show the feasibility of carbon neutrality within a discernable time. In doing so, we could only look at point-source emissions, which are still the major sources of CO_2 in the atmosphere from the United States. If the U.S. would be willing to spend $52 billion a year for five years and then $93.96 billion a year from then on, it could reduce its carbon emissions by twenty percent and be carbon neutral for point-sources by 2077, ten years *before* neutrality by alternative energy sources alone. What is important to realize about this model is that 2077 is not the “end-all be-all” for point-source neutrality. Based on how much the U.S. government is willing to spend, it can reach point-source neutrality even earlier. It would then be up to the citizens to push for neutrality in other areas, such as in residential and automotive energy efficiency. Thus it *is* feasible to reach carbon neutrality for a major portion of U.S. emissions and be on our way to neutrality in all areas, thus serving as a model for other nations to solve the crisis we find ourselves in.

To The Congress of The United States of America:

We all have heard that this is supposed to be a year of change. The problem with this slogan is that it ignites partisanship within our great nation. But the one issue that should not be partisan in any way is that of our emission levels and carbon output that are so harshly affecting our earth and our great nation.

The current proposed annual budget of the U.S. Department of Energy is $25 billion. If these funds were to be funneled away from all current DOE projects and into a major initiative to sequester carbon dioxide, only the equivalent of 5% of the current CO_2 emissions could be sequestered per year *after* the construction of pipeline to transport the carbon dioxide, making the U.S. carbon neutral by 2092, which is five years after the date when point-source carbon emissions per year reach zero due to increased generation of alternative energy (2087). However, the U.S. can gain ten years by spending more money now on sequestration. By spending $52.62 billion a year for five years to build a pipeline system and then spending $93.96 billion a year, the U.S. can eliminate the net emissions of point sources by the year 2077. Ten years may not seem like much when it is so far in the future, but this ten years accounts for 20% of all potential point-source carbon emissions between now and that time. Imagine how quickly the earth could begin to heal, without this 20% in its atmosphere. Also, this plan is safe, as the carbon dioxide will be injected deep into the earth, were it cannot harm plant or animal life and will be closely monitored. It is imperative that you act.

Sure, a plan to eliminate carbon dioxide emissions will cost a large sum of money, and it is possible that many of you will not live long enough to witness its full implementation, but by voting through our plan today, you will be giving the greatest gift to your children, and our children, and their children that you can possibly imagine. This is the gift of a future free from worry about the environment, and free from wishes that change had begun years before. Ladies and gentlemen, the future is approaching fast and hopefully you will remember your duties to guarantee it for all of us.

Yours Sincerely,
Team 2008

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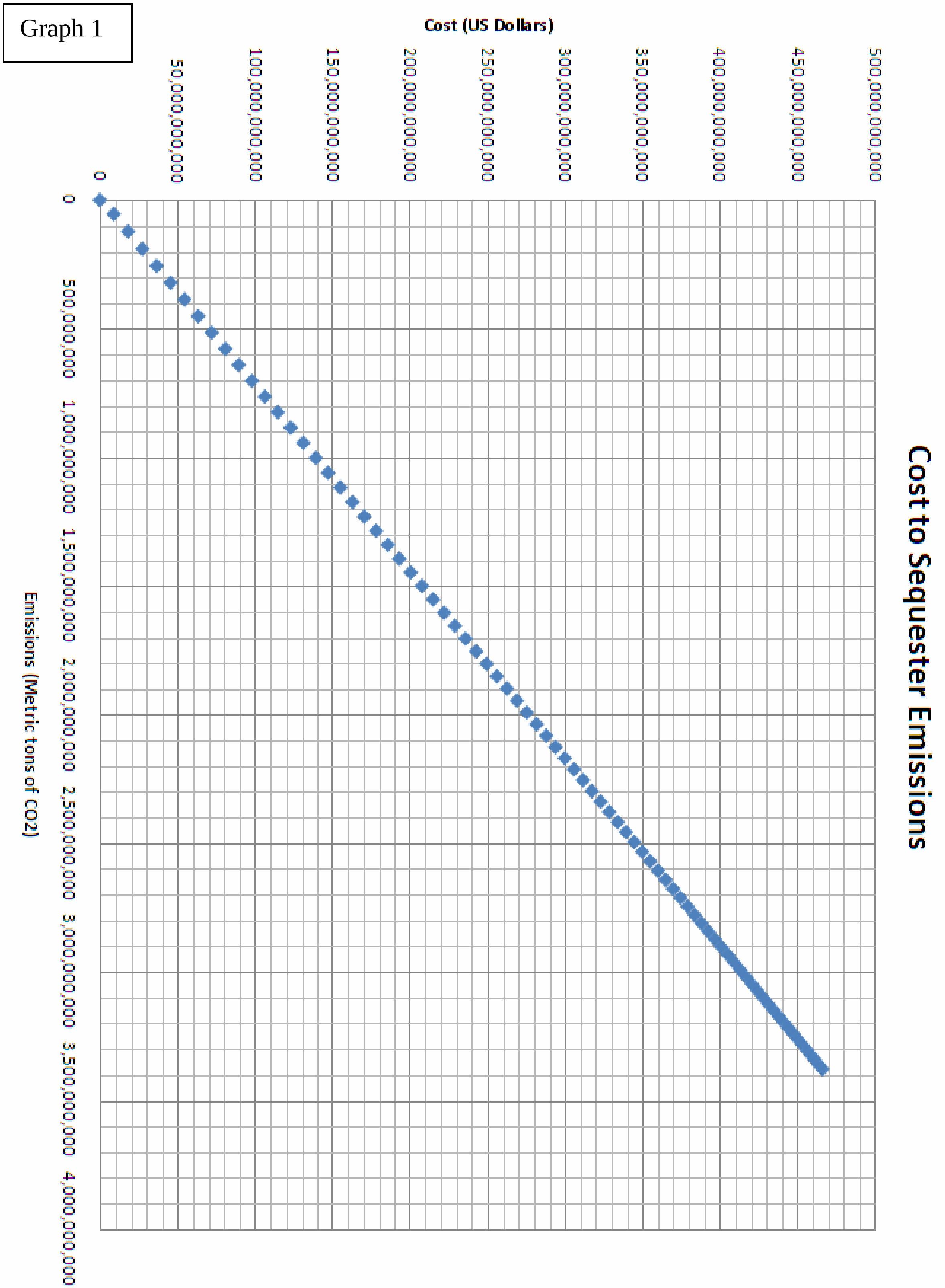
Appendix

Table 1 – Projection of Power Generation (in megawatts) for each Source of Alternative Energy and Estimated Decrease in Carbon Emission

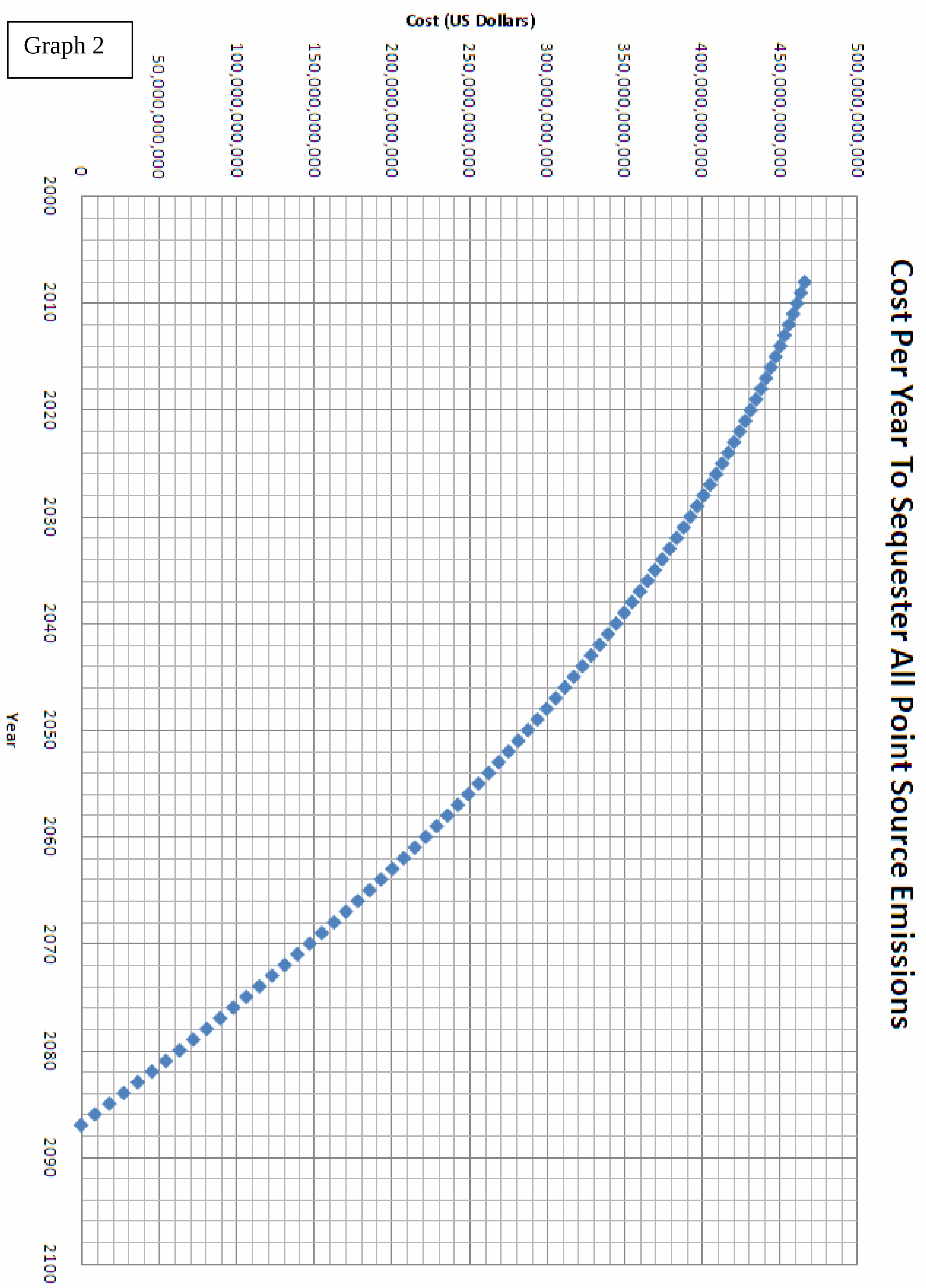
Time	Wood	Geothermal	Solar	Wind	Nuclear	Hydroelectric	Total MW energy	amount of carbon
2008	38428	15031	573	36278	832943	251984	1175238	3377241425
2009	38562	15213	579	42697	846384	247235	1190669	3359778181
2010	38695	15416	585	49671	859825	242486	1206678	3341661840
2011	38828	15640	591	57200	873266	237738	1223263	3322892402
2012	38962	15886	597	65286	886707	232989	1240426	3303469868
2013	39095	16153	603	73927	900148	228240	1258165	3283394237
2014	39229	16441	609	83124	913589	223491	1276482	3262665509
2015	39362	16751	615	92876	927029	218742	1295376	3241283685
2016	39495	17083	621	103184	940470	213993	1314847	3219248764
2017	39629	17435	627	114049	953911	209244	1334895	3196560746
2018	39762	17809	633	125468	967352	204495	1355520	3173219632
2019	39895	18204	639	137444	980793	199746	1376723	3149225420
2020	40029	18621	646	149975	994234	194998	1398502	3124578113
2021	40162	19059	652	163062	1007675	190249	1420859	3099277708
2022	40295	19519	658	176705	1021116	185500	1443792	3073324207
2023	40429	20000	664	190903	1034557	180751	1467303	3046717609
2024	40562	20502	670	205657	1047998	176002	1491391	3019457914
2025	40696	21026	676	220967	1061439	171253	1516056	2991545123
2026	40829	21571	682	236832	1074880	166504	1541298	2962979235
2027	40962	22137	688	253254	1088320	161755	1567117	2933760250
2028	41096	22725	694	270231	1101761	157006	1593513	2903888169
2029	41229	23334	700	287763	1115202	152258	1620487	2873362991
2030	41362	23965	706	305852	1128643	147509	1648037	2842184716
2031	41496	24616	712	324496	1142084	142760	1676165	2810353344
2032	41629	25290	718	343696	1155525	138011	1704869	2777868876
2033	41762	25984	725	363452	1168966	133262	1734151	2744731311
2034	41896	26700	731	383763	1182407	128513	1764010	2710940650
2035	42029	27438	737	404630	1195848	123764	1794446	2676496892
2036	42163	28197	743	426053	1209289	119015	1825459	2641400037
2037	42296	28977	749	448031	1222730	114266	1857049	2605650085
2038	42429	29778	755	470566	1236171	109518	1889217	2569247037
2039	42563	30601	761	493656	1249611	104769	1921961	2532190892
2040	42696	31446	767	517301	1263052	100020	1955282	2494481650
2041	42829	32311	773	541503	1276493	95271	1989181	2456119312
2042	42963	33198	779	566260	1289934	90522	2023657	2417103876
2043	43096	34107	785	591573	1303375	85773	2058710	2377435345
2044	43229	35037	791	617442	1316816	81024	2094340	2337113716

2045	43363	35988	798	643866	1330257	76275	2130547	2296138991
2046	43496	36961	804	670846	1343698	71527	2167331	2254511169
2047	43629	37955	810	698382	1357139	66778	2204692	2212230251
2048	43763	38970	816	726473	1370580	62029	2242630	2169296235
2049	43896	40007	822	755121	1384021	57280	2281146	2125709123
2050	44030	41065	828	784323	1397462	52531	2320238	2081468915
2051	44163	42144	834	814082	1410902	47782	2359908	2036575609
2052	44296	43245	840	844397	1424343	43033	2400155	1991029207
2053	44430	44367	846	875267	1437784	38284	2440979	1944829709
2054	44563	45511	852	906693	1451225	33535	2482380	1897977113
2055	44696	46676	858	938674	1464666	28787	2524358	1850471421
2056	44830	47862	864	971212	1478107	24038	2566913	1802312632
2057	44963	49070	871	1004305	1491548	19289	2610045	1753500747
2058	45096	50299	877	1037953	1504989	14540	2653755	1704035765
2059	45230	51550	883	1072158	1518430	9791	2698041	1653917686
2060	45363	52822	889	1106918	1531871	5042	2742905	1603146510
2061	45497	54115	895	1142234	1545312	293	2788345	1551722238
2062	45630	55430	901	1178106	1558753	-4456	2834363	1499644869
2063	45763	56766	907	1214533	1572193	-9205	2880958	1446914403
2064	45897	58123	913	1251516	1585634	-13953	2928130	1393530841
2065	46030	59502	919	1289055	1599075	-18702	2975879	1339494182
2066	46163	60902	925	1327150	1612516	-23451	3024205	1284804426
2067	46297	62324	931	1365800	1625957	-28200	3073109	1229461574
2068	46430	63767	937	1405006	1639398	-32949	3122589	1173465625
2069	46563	65231	943	1444768	1652839	-37698	3172647	1116816579
2070	46697	66717	950	1485085	1666280	-42447	3223281	1059514436
2071	46830	68224	956	1525958	1679721	-47196	3274493	1001559197
2072	46963	69752	962	1567387	1693162	-51945	3326282	942950861
2073	47097	71302	968	1609372	1706603	-56693	3378648	883689429
2074	47230	72873	974	1651912	1720044	-61442	3431591	823774899
2075	47364	74466	980	1695008	1733484	-66191	3485111	763207273
2076	47497	76080	986	1738660	1746925	-70940	3539208	701986551
2077	47630	77715	992	1782868	1760366	-75689	3593883	640112731
2078	47764	79372	998	1827631	1773807	-80438	3649134	577585815
2079	47897	81050	1004	1872950	1787248	-85187	3704963	514405803
2080	48030	82750	1010	1918825	1800689	-89936	3761369	450572693
2081	48164	84470	1016	1965255	1814130	-94684	3818351	386086487
2082	48297	86213	1023	2012241	1827571	-99433	3875911	320947184
2083	48430	87976	1029	2059783	1841012	-104182	3934048	255154785
2084	48564	89761	1035	2107881	1854453	-108931	3992762	188709288
2085	48697	91568	1041	2156534	1867894	-113680	4052054	121610696
2086	48831	93395	1047	2205743	1881335	-118429	4111922	53859006
2087	48964	95245	1053	2255508	1894775	-123178	4172367	0

Graph 1


Cost to Sequester Emissions
Cost (US Dollars)
0
50,000,000,000
100,000,000,000
150,000,000,000
200,000,000,000
250,000,000,000
300,000,000,000
350,000,000,000
400,000,000,000
450,000,000,000
500,000,000,000
Emissions (Metric tons of CO2)
0
500,000,000
1,000,000,000
1,500,000,000
2,000,000,000
2,500,000,000
3,000,000,000
3,500,000,000
4,000,000,000

Graph 2


Cost Per Year To Sequester All Point Source Emissions
Cost (US Dollars)
0
50,000,000,000
100,000,000,000
150,000,000,000
200,000,000,000
250,000,000,000
300,000,000,000
350,000,000,000
400,000,000,000
450,000,000,000
500,000,000,000
Year
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100