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T4 ________________		F4 ________________

2008

11th Annual High School Mathematical Contest in Modeling (HiMCM) Summary Sheet

(Please attach a copy of this page to each copy of your Solution Paper.)

Team Control Number: 2084

Problem Chosen: B

Please type a summary of your results on this page. Please remember not to include the name of your school, advisor, or team members on this page.

The United States emissions are capped indefinitely at 6.02935 billion metric tons of carbon dioxide per year. The atmospheric carbon dioxide level as of 2007 is 765 billion metric tons, and it increases each year because the carbon dioxide emissions are greater than the carbon dioxide that is sequestered. The parameters of the problem do not allow us to change the emissions that are being produced, so the only way to neutralize the carbon dioxide in the atmosphere is to increase the amount of sequestration. Currently, terrestrial ecosystems sequester 1.2 billion metric tons of carbon per year, and oceans sequester 2.2 billion metric tons per year. We assume that we cannot change the amount carbon dioxide that is sequestered by oceans. We can increase the sequestration of terrestrial ecosystems through afforestation, reforestation, changes in in forest management (such as lengthening the harvest-regeneration cycle and using low-impact logging practices), conversion from conventional to reduced tillage, and the changing of grazing land management.

Another way that we can increase the carbon dioxide that is being sequestered is through artificial sequestration. This involves the process of geologic sequestration, which sequesters carbon dioxide emissions from industrial point sources, such as power plants and factories. Forty percent of the United States carbon dioxide emissions are due to the industrial sector. If a geologic sequestration system was installed at every industrial point source in the country, ninety percent of the industrial carbon dioxide emissions could be sequestered. However, this would be extremely expensive and unfeasible.

To neutralize the atmospheric carbon dioxide (make the carbon dioxide sequestration equal to the emissions of carbon dioxide), we would have to afforest 401,480,239 acres and reforested the same amount. We would need to install geologic sequestration systems at forty percent of the industrial point sources in the U.S. We would also have to change the forest management of the current acres of forest in the country, convert half of all of the cropland in the country from conventional to reduced to tillage, and change the grazing land management of all acres of all acres of grazing land in the country.

The 2008 High School Mathematical Contest in Modeling

Problem B: Going Green

Team 2084

Definition of Problem and Bounds

Global warming is a very controversial issue currently facing the world. Most national governments have signed and ratified the Kyoto Protocol, which aimed to reduce greenhouse gas emissions, but the United States did not participate. Regardless of whether or not global warming is occurring, the numbers show that carbon emissions today are been higher than ever, due to many different factors. Certain measures should be followed in order to reduce the amount of carbon emitted into the atmosphere, and there are two main approaches to solving this problem: lowering emissions or increasing methods of carbon dioxide consumption. Our problem was that we had to achieve carbon neutrality only by adjusting the amount of carbon absorbed. We had to create a model that would be feasible, effective and economically manageable.

Studies show that carbon emission in 2007 reached 6.02935 billion tons of carbon dioxide per year. We cannot reduce the amount of carbon dioxide emitted into the atmosphere, because the emission levels are capped, we can only increase the amount of carbon dioxide consumption (sequestration) per year. This means the earth needs to consume 6.02935 billion tons of carbon in order to achieve neutrality; and we would need to consume more carbon dioxide than we emit in order to reduce the amount of carbon dioxide in the atmosphere. We define neutrality where the amount of carbon emitted into the atmosphere is equivalent to the amount of carbon consumed; the amount of carbon in the atmosphere is neither growing nor decreasing. Optimum conditions would be where the amount of carbon dioxide in the atmosphere is decreasing. Our plan is to find appropriate balance of reforestation, afforestation, and geological sequestration that will neutralize the carbon emissions and be cost efficient.

Assumptions and Justifications

I. General Assumptions

- There are a capped 6.02935 billion tons of carbon emissions each year in the U.S.
- There are 750 million acres of forest in the U.S.
- There are 442 million acres of cropland
- The atmosphere exists only above the United States, where atmospheric changes are only nationally and not globally.
- One half of the cropland is already no till
- There are 261 million acres of grazing lands
- The cost the U.S. Forest Service spends on its forests is how much it costs to manage a forest at its healthiest level
- No companies are artificially sequestering

These assumptions were based off of the most up to date data we could find (sources found in bibliography). We assumed that we could only change half of the cropland because there are many farms that already do not till their land. We based this off of a number we found in a study of Kansas farmers as well as the current global economy. We found an article that studied farms over the past year and found that farmers have already switched over to no-till farming. Based on the sources we think that it is realistic that half the farms already do no-till farming. We assumed that no companies were artificially sequestering because the number that do is too minimal to quantify.

II. Cost Assumptions

- For reforestation we have to pay for preparation of all the sites
- Cost of reforestation is $165 per acre
- Cost afforestation is $182.11 per acre
- We have an infinite amount of money to work with

- There is not a significant cost difference between tilled and non-tilled farms
- It costs 73$ to sequester one metric ton of Carbon Dioxide

We assumed that we had an infinite amount of money although we are looking to minimize the amount of money spent. The prices we used were based off the most up to date data we could find. To insure that are price numbers were as accurate as possible we too the average of the lowest it would cost and the most it would cost. We also crosschecked our numbers with multiple sources. Since the cost difference between tilling and non-tilling is minimal we assumed it would not cost the government anything, just save the farmers money.

III. Sequestration Amount Assumptions

- The ocean sequesters 2.2 billion metric tons of carbon each year
- The amount the ocean sequesters can't be changed
- Terrestrial ecosystems sequester 1.2 billion metric tons of carbon each year
- Per acre of afforestation 1.6 metrics tons is sequestered per year
- Per acre of reforestation 1.2 metric tons is sequestered per year
- Per acre of change in forest management .7 metric tons is sequestered per year
- Per acre of agricultural land changed from conventional to reduced tillage .2 metric tons is sequestered per year
- Acres of forest never stop sequestering carbon dioxide
- One half of the cropland can be turned into no till cropland
- The forests are all made up of trees that sequester the same amount
- All "free land" not attributed to forests, grazing lands or croplands is at our disposal and can be converted to forest
- All available acres of grazing land are managed through grazing land management
- All available acres of cropland are converted from conventional to reduced tillage

We assumed that these numbers based on the most accurate environmental reports. We had to assume that acres of forest never stopped sequestering to simplify the model. Usually the trees stop sequestering after 80 years, so in the short term there would not be a big effect. Since we can't accurately quantify the amount of each tree variety we took the average sequestration for trees.

Atmospheric Carbon Dioxide Model

We used the program Stella 9.0.2 to model to show how carbon is currently absorbed into the atmosphere and the different factors, emitting or consuming carbon into or from the atmosphere, could affect the overall level of carbon in the atmosphere. Because our question focused around sequestration, or reduction of carbon emissions and determining if neutrality could be achieved, our model is particularly useful as it allows for easy change in rates of sequestration. The following is a description of how our model works; all the different variables can be viewed in Appendix A. We capped the total carbon dioxide emissions of the United States at 6.02935 billion tons per year. Therefore, the amount of carbon dioxide that is added to the atmosphere each year is equal to the total emissions minus the amount of carbon dioxide that is sequestered, so both the Total U.S. CO_2 Emissions and Sequestration flow into Change in CO_2. The Change in CO_2 is added each year to the CO_2 in Atmosphere and generates the cumulative atmospheric carbon dioxide. As of 2007, the level of atmospheric carbon dioxide is 765 billion metric tons. Terrestrial Ecosystems, Oceans, and Artificial Sequestration flow into Sequestration. Current Terrestrial Ecosystem Sequestration is set at 1.2, because 1.2 billion metric tons of carbon dioxide are currently sequestered by terrestrial ecosystems. We can increase Terrestrial Ecosystems sequestration through a number of factors.

Afforestation is the planting of forests on land that has not been forested previously. Every acre of afforestation sequesters $1.6\text{x}10^{-9}$ billion metric tons of CO_2 per year. Therefore, Afforestation is equal to $(1.6\text{x}10^{-9})$*Acres of Afforestation. Afforestation, and flows into Sequestration and adds to the total amount of carbon dioxide that is sequestered.

Reforestation is the planting of forests that land that has been forested previously. Every acre of reforestation sequesters $1.2\text{x}10^{-9}$ billion metric tons of CO_2 per year. Therefore, Reforestation is equal to $(1.2\text{x}10^{-9})$*Acres of Reforestation. Reforestation also flows into Sequestration and adds to the sequestered CO_2.

Changes in forest management also contribute to sequestration. These changes include using low-impact logging practices and lengthening the harvest-regeneration cycle. Every acre that adopts forest management practices sequesters $7x10^{-10}$ billion metric tons of CO_2 per year. It is improbable that every acre of current forest can adopt these practices, and there may well be some forests that have already adopted them. Therefore, we should not assume that all of the current acres of forest have the possibility of sequestering more carbon dioxide than they already do. We will use a percentage of the Current Acres of Forest to flow into the Changes in Forest Management. We will test different acreages of forest that will flow into Changes in Forest Management to find the most plausible and cost efficient method. The maximum acreage that we can test is 750 million, which is the total acreage of forests in the US, but it is improbable. The Changes in Forest Management is equal to $(7x10^{-10})$*Acres of Forests, and flows into Terrestrial Ecosystems, which flows into Sequestration.

Conversion from conventional to reduced tillage allows soil carbon to accumulate and increases sequestration. Ever acre that is converted to reduced tillage sequesters $2x10^{-10}$ billion metric tons of carbon per year. Many farms already use no-till processes, so we cannot assume that all of the cropland in the US has the potential to be converted. As stated above, we assumed that one half of the cropland in the US could be converted to no-till farming. Therefore, we can attempt to convert half of the 442 million acres of cropland in the US. Conversion from Conventional to Reduced Tillage is equal to $(2x10^{-10})$*(.5*Acres of Cropland), which flows into Terrestrial Ecosystems and adds to Sequestration.

Changes in grazing land management include processes such as rotational grazing, which increase carbon sequestration in soil. Every acre that changes to the improved land management practices sequesters $2.6x10^{-10}$ billion metric tons per year. The maximum number of acres that we could test in our model is 261 million, which is the total acreage of grazing land in the US. However, this is very improbable because many farms already use these practices, so we will test different acreages to find the most probable model. Changes in Grazing Land Management equals $(2.6x10^{-10})$*(Acres of Grazing Land), which flows into Terrestrial Ecosystems and into Sequestration.

We assumed that we could not change the sequestration of oceans, so Oceans is set at 2.2 billion metric tons per year. This flows into Sequestration. The last factor that flows into Sequestration is Artificial Sequestration is. The primary method of artificial sequestration is geologic sequestration. Geologic sequestration is a process that takes the CO_2 emissions from industrial point sources, such as power plants and factories. This process takes the carbon emissions in the air and usually turns it into a liquid, which can be stored far below earth's surface in depleted oil, natural gas and coal reservoirs, loose soils and porous rock layers. This process can significantly lower CO_2 emissions from point sources. The industrial emissions sector contributes 40% of the total US carbon dioxide emissions. Therefore, Industrial Emissions equals .4*(Total US CO_2 Emissions). At most, geologic sequestration can sequester 90% of the total industrial emissions. However, this would mean a geologic sequestration system would have to be set up at every industrial power plant in the country, which would be extremely expensive. We will test different percentages of the industrial emissions that geologic sequestration will sequester in order to create a plausible and cost effective model. Geologic Sequestration equals % sequestered*(Industrial Emissions). This will flow into Artificial Sequestration, and into Sequestration.

Cost Model

To address the issue of cost, we created a second model that would demonstrate the annual costs of all the sequestration processes presented in our other model of CO_2 in the atmosphere (See Appendix B). We again used the Stella program to model this situation. We began by determining the costs of sequestration-increasing factors from our other model. The methods included in the other model were artificial sequestration, afforestation, reforestation, forest management, changes in grazing land management, and tilling changes.

TO create this model we used the factors from the first model and multiplied them by a yearly cost, and then add all these costs together to create a total yearly cost. Therefore, the main task in creating this model was determining the yearly cost of each method of sequestration. First we assumed that changes in grazing land and tillage changes would have no significant costs, and in fact a lot of our research has said that farmers who utilize these practices have actually saved money. So, we do not factor them into our cost equation. To determine the cost of forest management, we researched the US Forest Service Budget. We assume that the money that the US Forest Service spends on maintaining its forests is the amount necessary for one to maintain a forest to its healthiest level and the level at which the most sequestration will occur. The annual budget spent on all forest regulations, minus land acquisition, was $4,369,471. The Forest Service maintains 193 million acres, and assuming they spread their resources equally on each acre of land. Therefore, each year, it costs about $0.02 to maintain 1 acre of forest.

For Reforestation, research showed that with site preparation, the cost per acre would be $165. We assumed that we had to prepare our sites for reforestation, so we priced each acre at $165. Research also showed that afforestation costs estimated $450 per hectare. Through using conversion charts, this showed that afforestation estimated at $182.11 per acre. To determine the cost of artificial sequestration, we first began with the cost of removing and storing CO_2, which is about $53,000,000,000 for a billion metric tons of CO_2. The amount of CO_2 that is possible for sequestration varies though, which is shown in our other models. We took all these prices for various methods, multiplied by the different amounts of afforestation, reforestation, etc. and were able to compile an annual cost.

Testing and Our Solution and Conclusions

With our model set up, we began to test various values of different methods of sequestration to try to achieve neutrality and cost efficiency. The possible factors we determined for sequestration were changes in grazing land management, changes in forest management, conversion from conventional to reduced tillage, geological sequestration, reforestation, and afforestation. The first test we did was a baseline graph with no sequestration factors involved to see what would happen without interference (See Appendix C1). Relating this to our cost model, obviously with no methods added, the cost remains at 0. Our next test was that we compared each method of sequestration. We turned on each method of sequestration at a time and kept all the others off. In this way, we could clearly see the impacts of each method of sequestration on the amount of carbon present in the atmosphere. (See Appendix C2). Three of the methods of sequestration have adjustable rates: the rate of geological sequestration, the acres of reforestation, and the acres of afforestation. We decided to use the highest value possible for each method of sequestration, sometimes even if that number was not feasible, to most clearly show the impacts of each factor. For geologic sequestration, we assumed that every point source of carbon emissions would utilize geologic sequestration, when in reality only a percent of point sources actually implement geologic sequestration technology. Also, we calculated the area of "free" space in the US. We found the total area of the United States, then subtracted from this value the area of forests, grazing land and cropland. This got us the value of 810,960,478 acres of "free space". We then made the assumption that all of this land could be used for afforestation and reforestation, when in reality other human structures such as cities, roads, and houses are significantly decreasing this area. For this particular test, we used maximum numbers in order to show which method of sequestration yields the greatest change in carbon. After this, we applied this same method to our cost model (See Appendix C3), and again we could see which method individually would be the most cost effective. Looking at these two graphs, we determined that geological sequestration was the most effective technique for reducing emissions. The cost model showed that maintaining forests is the most cost effective method. Our tests showed that using just one method of sequestration, even at the maximum levels, is not capable of achieving carbon neutrality.

Next, we tried to manipulate the levels of each sequestration method to achieve neutrality. It took us quite a few tries to adjust levels of sequestration methods to create a neutral situation (Appendix C4). We concluded that if we set equal values of 401,480,239 acres for afforestation and reforestation, turned all other factors on, and had 40% of all point sources practice geological sequestration, the amount of carbon emitted and the amount of carbon sequestered would be equal, thus achieving neutrality. This model works perfectly mathematically, but is not feasible or economically legitimate. This is not feasible firstly because the amount of land we attributed to afforestation and reforestation (802,960,478 acres, which is only about 2,000,000 acres less than the unrealistic amount of "free" space previously discussed) still does not account for the amount of land taken up by human constructions and other environments that could not be developed into forests. Another issue was that we assumed that all acres of grazing land and cropland were improved to create more sequestration, a highly unlikely process. We also assumed that no grazing land is already using the improved methods of grazing, when in reality many farms may already be practicing them. Also, this model is extremely cost-inefficient (Appendix C5). The calculated annual cost for this program of sequestration would amount to $139,357,805,759.29, *per year*. However, this does keep the carbon emissions that we are producing in check. If we increase the amount of afforestation or reforestation it is possible to create such a great amount of sequestration that we can begin to decrease carbon in the atmosphere. In other words, the rate of sequestration is higher than emissions.

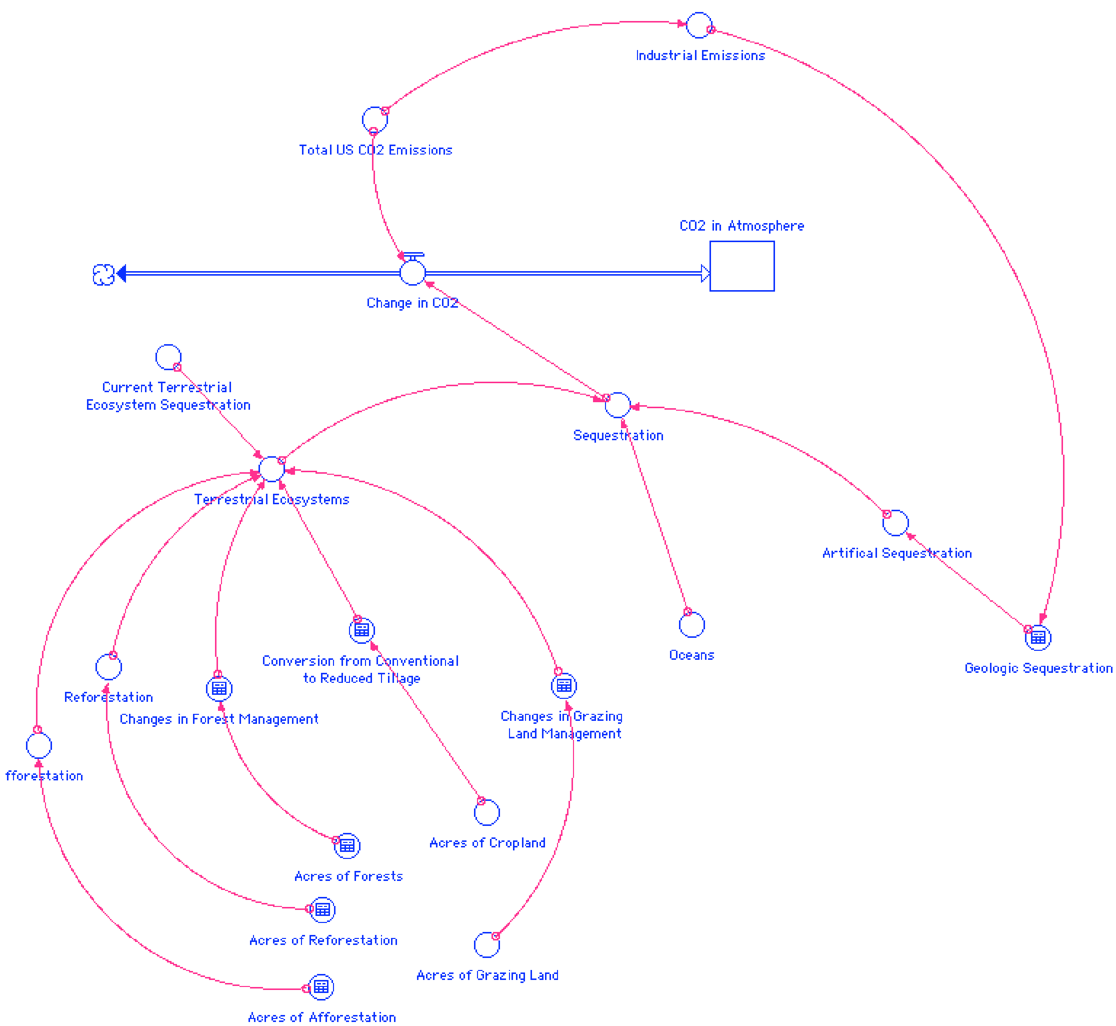
After this analysis of cost and feasibility we have determined that it is very difficult, if not completely impossible, to control our outputs of carbon emissions by using sequestration techniques with today's technology. A cost effective and feasible solution might be possible through the lowering of carbon dioxide emissions. To achieve carbon neutrality, we would have to create a balance between lowering carbon emissions and increasing sequestration.

Strengths and Weaknesses of Our Model

The strength of our model is that it includes a lot of research and data from reliable sources. Our information can be backed up from multiple respectable sources that strengthen the validity of our information. Our model shows many different methods of sequestration, which shows all consideration of the many different factors and creates a more realistic model. We followed the guidelines provided, which meant that we could not reduce the number of CO_2 emitted into the atmosphere, we could only increase the amount of consumption.

The weakness of our model is that we had to use many assumptions because a lot of the factors involved in our model were different to accurately quantify. Therefore, we used numbers from our most reliable sources and made them assumptions. We had to make assumptions with certain numbers because some numbers vary depending on the source. We followed after our most reliable sources. Also, we had to average the high and low bounds from a range of values. We do not believe that the averages will have a great impact on the results because they are considering all the values in the range. Some things we could not include in our model because there was no way of quantifying it, such as riparian boarders that prevent erosion and add to sequestration because we could not calculate the number of acres of riparian land that has not been forested.

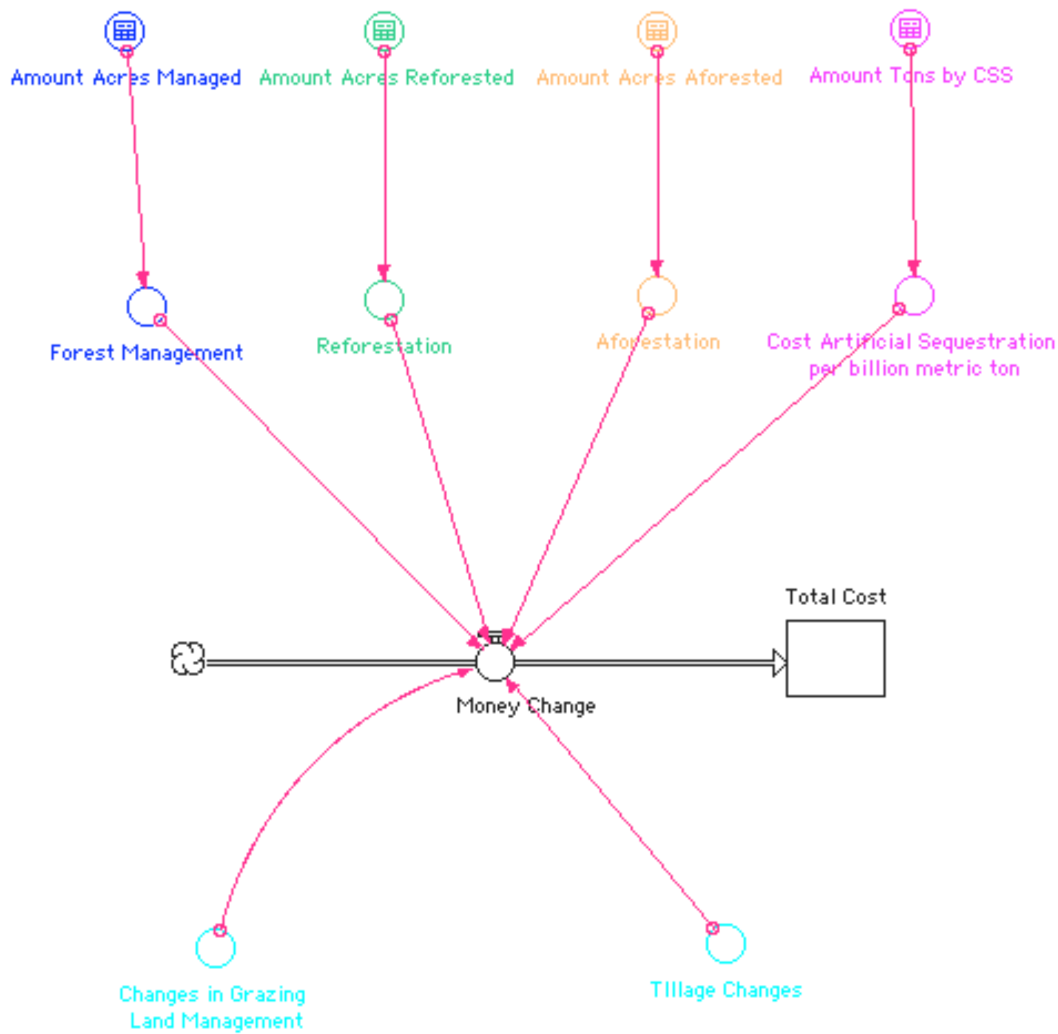
Appendix A.



Above is the model of our Stella diagram, showing the carbon dioxide consumption rate and how all of the factors in the consumption are connected. The following shows the formulas for the Stella model that match each label above.

```
CO2_in_Atmosphere(t) = CO2_in_Atmosphere(t - dt) + (Change_in_CO2) * dt
INIT CO2_in_Atmosphere = 765
INFLOWS:
    Change_in_CO2 = Total_US_CO2_Emissions-Sequestration
Acres_of_Afforestation = 0
Acres_of_Cropland = 442000000
Acres_of_Forests = 750000000
Acres_of_Grazing_Land = 261000000
Acres_of_Reforestation = 0
Afforestation = (1.6*10^-9)*Acres_of_Afforestation
Artifical_Sequestration = Geologic_Sequestration
Changes_in_Forest_Management = (7*10^-10)*Acres_of_Forests
Changes_in_Grazing_Land_Management = (2.6*10^-10)*Acres_of_Grazing_Land
Conversion_from_Conventional_to_Reduced_Tillage = (2*10^-10)*(.5*Acres_of_Cropland)
Current_Terrestrial_Ecosystem_Sequestration = 1.2
Geologic_Sequestration = .9*(.4  *Industrial_Emissions)
Industrial_Emissions = .4*Total_US_CO2_Emissions
Oceans = 2.2
Reforestation = (1.2*10^-9)*Acres_of_Reforestation
Sequestration = Terrestrial_Ecosystems+Oceans+Artifical_Sequestration
Terrestrial_Ecosystems = Afforestation+Changes_in_Forest_Management+Changes_in_Grazing_Land_Management+
Current_Terrestrial_Ecosystem_Sequestration+Reforestation+Conversion_from_Conventional_to_Reduced_Tillage
Total_US_CO2_Emissions = 6.02935
```

Appendix B.



Above is the model of our second Stella diagram, showing the yearly costs of each method of sequestration . The following shows the formulas for the this model that matches the model above.

Total_Cost(t) = Total_Cost(t - dt) + (Money_Change) * dt
INIT Total_Cost = 0
INFLOWS:

Money_Change = Reforestation+Aforestation+TIllage_Changes+Forest_Management+Changes_in_Grazing_Land_Management+Cost_Artificial_Sequestration_per_billion_metric_ton

Aforestation = Amount_Acres_Aforested*182.11

Amount_Acres_Aforested = 401480239

Amount_Acres_Managed = 750000000

Amount_Acres_Reforested = 401480239

Amount_Tons_by_CSS = .87

Changes_in_Grazing_Land_Management = 0

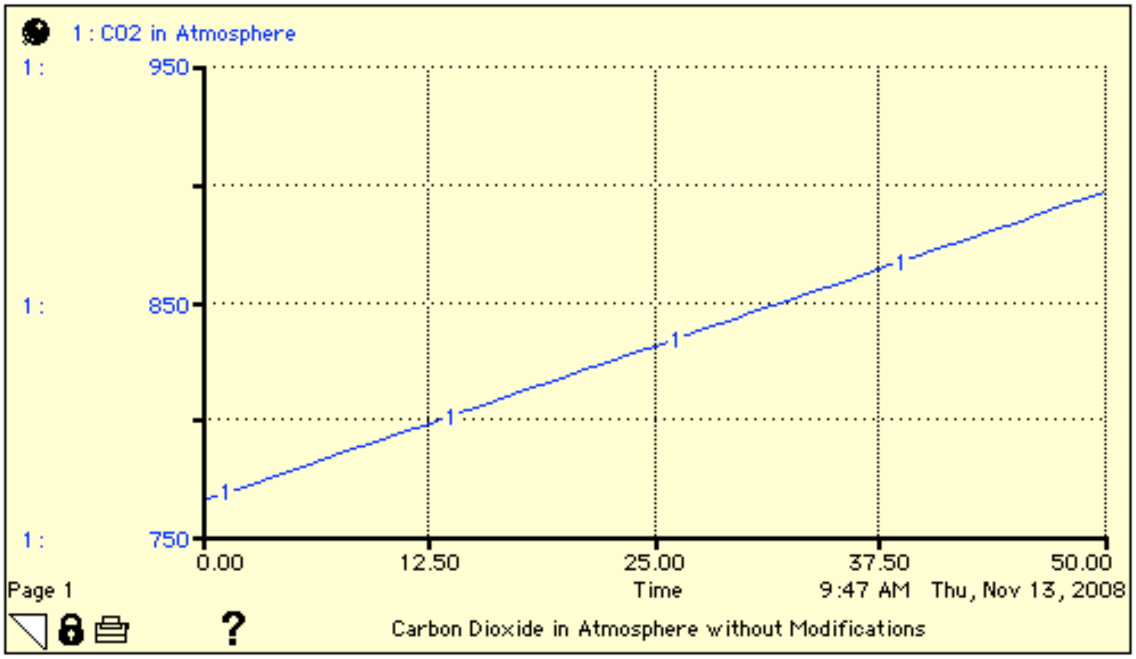
Cost_Artificial_Sequestration_per_billion_metric_ton = 53000000000*Amount_Tons_by_CSS

Forest_Management = .02*Amount_Acres_Managed

Reforestation = Amount_Acres_Reforested*165

TIllage_Changes = 0

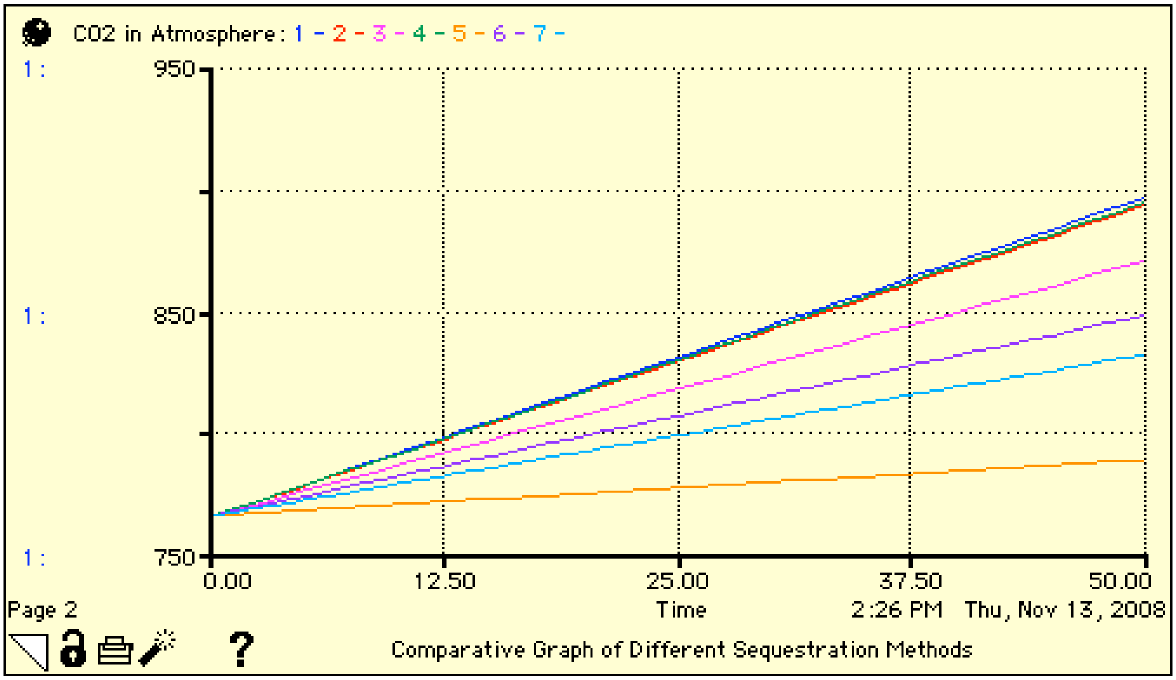
Appendix C1


1 : CO2 in Atmosphere
1 :
950
1 :
850
1 :
750
0.00
12.50
25.00
37.50
50.00
Time
Page 1
9:47 AM Thu, Nov 13, 2008
Carbon Dioxide in Atmosphere without Modifications

Time	CO2 in Atmo
0	765.00
1	767.63
2	770.26
3	772.89
4	775.52
5	778.15
6	780.78
7	783.41
8	786.03
9	788.66
10	791.29
11	793.92
12	796.55
13	799.18
14	801.81
15	804.44
16	807.07
17	809.70
18	812.33
19	814.96
20	817.59
21	820.22
22	822.85
23	825.48
24	828.10
25	830.73

Time	CO2 in Atmo
25	830.73
26	833.36
27	835.99
28	838.62
29	841.25
30	843.88
31	846.51
32	849.14
33	851.77
34	854.40
35	857.03
36	859.66
37	862.29
38	864.92
39	867.54
40	870.17
41	872.80
42	875.43
43	878.06
44	880.69
45	883.32
46	885.95
47	888.58
48	891.21
49	893.84
Final	896.47

Appendix C2



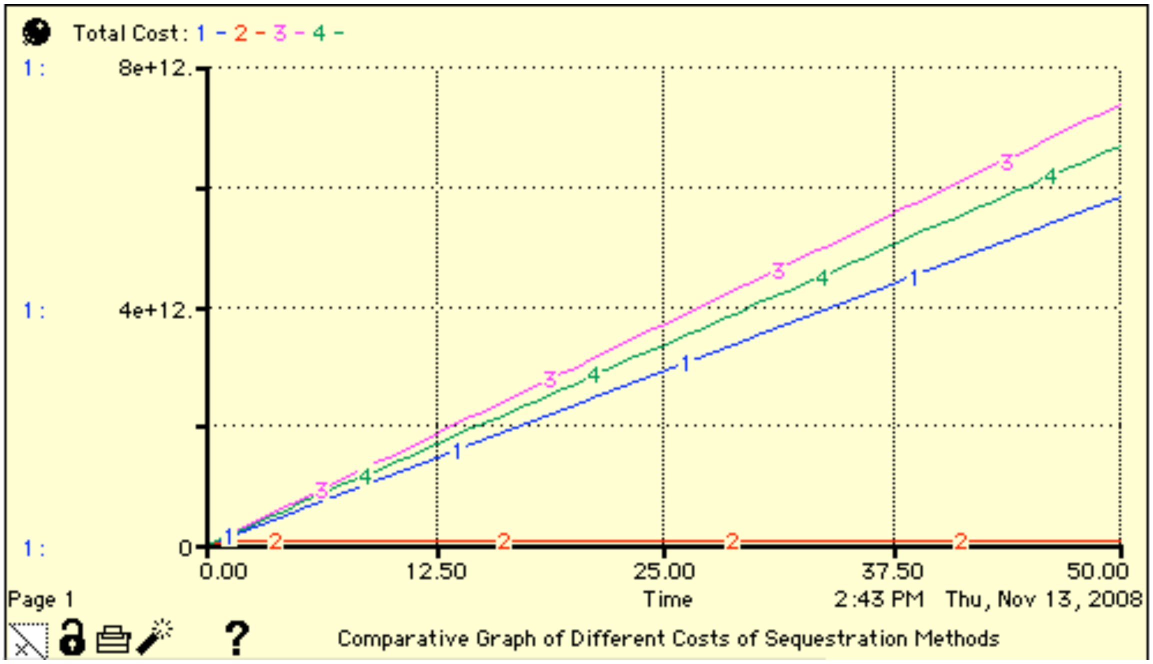
This graph shows the comparison of the different sequestration methods used. It shows that one single method does not successfully achieve neutrality.

Trial Number (color of line)	Single Sequestration Factor Activated to Maximum Level
1 (blue)	None activated
2 (red)	Changes in Grazing and Land Management
3 (pink)	Changes and Forest Management
4 (green)	Changes from Conventional to Reduced Tillage
5 (orange)	Geological Sequestration
6 (purple)	Reforestation
7 (teal)	Afforestation

2:26 PM 11/13/08 Table 1 : p2 (Comparative Table of Different Sequestration Methods)

Time	1 : CO2 in Atmosphere	2 : CO2 in Atmosphere	3 : CO2 in Atmosphere	4 : CO2 in Atmosphere	5 : CO2 in Atmosphere	6 : CO2 in Atmosphere	7 : CO2 in Atmosphere
0	765.00	765.00	765.00	765.00	765.00	765.00	765.00
1	767.63	767.56	767.10	767.59	765.46	766.66	766.33
2	770.26	770.12	769.21	770.17	765.92	768.31	767.66
3	772.89	772.68	771.31	772.76	766.38	769.97	769.00
4	775.52	775.25	773.42	775.34	766.84	771.62	770.33
5	778.15	777.81	775.52	777.93	767.29	773.28	771.66
6	780.78	780.37	777.63	780.51	767.75	774.94	772.99
7	783.41	782.93	779.73	783.10	768.21	776.59	774.32
8	786.03	785.49	781.83	785.68	768.67	778.25	775.65
9	788.66	788.05	783.94	788.27	769.13	779.91	776.99
10	791.29	790.61	786.04	790.85	769.59	781.56	778.32
11	793.92	793.18	788.15	793.44	770.05	783.22	779.65
12	796.55	795.74	790.25	796.02	770.51	784.87	780.98
13	799.18	798.30	792.36	798.61	770.96	786.53	782.31
14	801.81	800.86	794.46	801.19	771.42	788.19	783.65
15	804.44	803.42	796.57	803.78	771.88	789.84	784.98
16	807.07	805.98	798.67	806.36	772.34	791.50	786.31
17	809.70	808.55	800.77	808.95	772.80	793.16	787.64
18	812.33	811.11	802.88	811.53	773.26	794.81	788.97
19	814.96	813.67	804.98	814.12	773.72	796.47	790.30
20	817.59	816.23	807.09	816.70	774.18	798.12	791.64
21	820.22	818.79	809.19	819.29	774.63	799.78	792.97
22	822.85	821.35	811.30	821.87	775.09	801.44	794.30
23	825.48	823.91	813.40	824.46	775.55	803.09	795.63
24	828.10	826.48	815.50	827.04	776.01	804.75	796.96
25	830.73	829.04	817.61	829.63	776.47	806.40	798.30
25	830.73	829.04	817.61	829.63	776.47	806.40	798.30
26	833.36	831.60	819.71	832.21	776.93	808.06	799.63
27	835.99	834.16	821.82	834.80	777.39	809.72	800.96
28	838.62	836.72	823.92	837.38	777.85	811.37	802.29
29	841.25	839.28	826.03	839.97	778.30	813.03	803.62
30	843.88	841.84	828.13	842.55	778.76	814.69	804.95
31	846.51	844.41	830.23	845.14	779.22	816.34	806.29
32	849.14	846.97	832.34	847.72	779.68	818.00	807.62
33	851.77	849.53	834.44	850.31	780.14	819.65	808.95
34	854.40	852.09	836.55	852.90	780.60	821.31	810.28
35	857.03	854.65	838.65	855.48	781.06	822.97	811.61
36	859.66	857.21	840.76	858.07	781.52	824.62	812.95
37	862.29	859.78	842.86	860.65	781.98	826.28	814.28
38	864.92	862.34	844.97	863.24	782.43	827.94	815.61
39	867.54	864.90	847.07	865.82	782.89	829.59	816.94
40	870.17	867.46	849.17	868.41	783.35	831.25	818.27
41	872.80	870.02	851.28	870.99	783.81	832.90	819.60
42	875.43	872.58	853.38	873.58	784.27	834.56	820.94
43	878.06	875.14	855.49	876.16	784.73	836.22	822.27
44	880.69	877.71	857.59	878.75	785.19	837.87	823.60
45	883.32	880.27	859.70	881.33	785.65	839.53	824.93
46	885.95	882.83	861.80	883.92	786.10	841.19	826.26
47	888.58	885.39	863.90	886.50	786.56	842.84	827.60
48	891.21	887.95	866.01	889.09	787.02	844.50	828.93
49	893.84	890.51	868.11	891.67	787.48	846.15	830.26
Final	896.47	893.07	870.22	894.26	787.94	847.81	831.59

Appendix C3



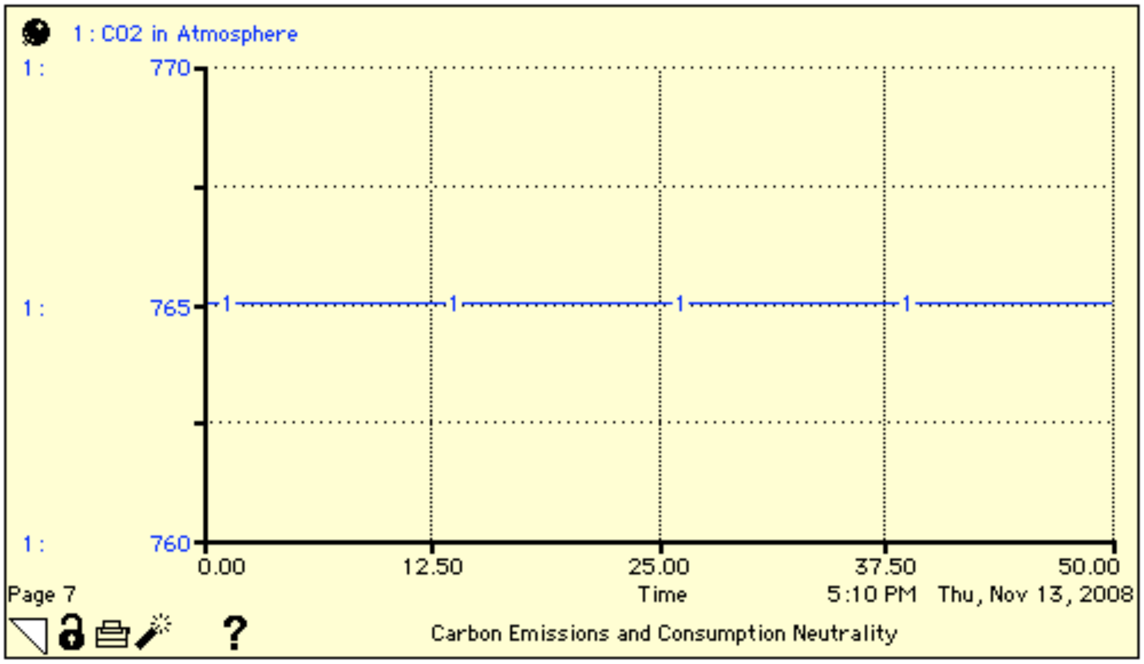
This graph shows the comparison of the different costs of sequestration methods used. It shows the different costs of each method of sequestration.

Trial Number (color of line)	Single Cost of Sequestration Method Activated to Maximum Level
1 (blue)	Geological Sequestration
2 (red)	Forest Managed
3 (pink)	Afforestation
4 (green)	Reforestation

2:43 PM 11/13/08 Table 1 (Comparative Table of Different Costs of Sequestration Methods)

Time	1 : Total Cost	2 : Total Cost	3 : Total Cost	4 : Total Cost
0	0.00	0.00	0.00	0.00
1	116,600,000,000.00	1,500,000.00	147,675,903,043.80	133,808,478,870.00
2	233,200,000,000.00	3,000,000.00	295,351,806,087.60	267,616,957,740.00
3	349,800,000,000.00	4,500,000.00	443,027,709,131.40	401,425,436,610.00
4	466,400,000,000.00	6,000,000.00	590,703,612,175.20	535,233,915,480.00
5	583,000,000,000.00	7,500,000.00	738,379,515,219.00	669,042,394,350.00
6	699,600,000,000.00	9,000,000.00	886,055,418,262.80	802,850,873,220.00
7	816,200,000,000.00	10,500,000.00	1,033,731,321,306.60	936,659,352,090.00
8	932,800,000,000.00	12,000,000.00	1,181,407,224,350.40	1,070,467,830,960.00
9	1,049,400,000,000.00	13,500,000.00	1,329,083,127,394.20	1,204,276,309,830.00
10	1,166,000,000,000.00	15,000,000.00	1,476,759,030,438.00	1,338,084,788,700.00
11	1,282,600,000,000.00	16,500,000.00	1,624,434,933,481.80	1,471,893,267,570.00
12	1,399,200,000,000.00	18,000,000.00	1,772,110,836,525.60	1,605,701,746,440.00
13	1,515,800,000,000.00	19,500,000.00	1,919,786,739,569.40	1,739,510,225,310.00
14	1,632,400,000,000.00	21,000,000.00	2,067,462,642,613.20	1,873,318,704,180.00
15	1,749,000,000,000.00	22,500,000.00	2,215,138,545,657.00	2,007,127,183,050.00
16	1,865,600,000,000.00	24,000,000.00	2,362,814,448,700.80	2,140,935,661,920.00
17	1,982,200,000,000.00	25,500,000.00	2,510,490,351,744.60	2,274,744,140,790.00
18	2,098,800,000,000.00	27,000,000.00	2,658,166,254,788.40	2,408,552,619,660.00
19	2,215,400,000,000.00	28,500,000.00	2,805,842,157,832.20	2,542,361,098,530.00
20	2,332,000,000,000.00	30,000,000.00	2,953,518,060,876.00	2,676,169,577,400.00
21	2,448,600,000,000.00	31,500,000.00	3,101,193,963,919.80	2,809,978,056,270.00
22	2,565,200,000,000.00	33,000,000.00	3,248,869,866,963.60	2,943,786,535,140.00
23	2,681,800,000,000.00	34,500,000.00	3,396,545,770,007.40	3,077,595,014,010.00
24	2,798,400,000,000.00	36,000,000.00	3,544,221,673,051.20	3,211,403,492,880.00
25	2,915,000,000,000.00	37,500,000.00	3,691,897,576,095.00	3,345,211,971,750.00
Time	1 : Total Cost	2 : Total Cost	3 : Total Cost	4 : Total Cost
25	2,915,000,000,000.00	37,500,000.00	3,691,897,576,095.00	3,345,211,971,750.00
26	3,031,600,000,000.00	39,000,000.00	3,839,573,479,138.80	3,479,020,450,620.00
27	3,148,200,000,000.00	40,500,000.00	3,987,249,382,182.60	3,612,828,929,490.00
28	3,264,800,000,000.00	42,000,000.00	4,134,925,285,226.40	3,746,637,408,360.00
29	3,381,400,000,000.00	43,500,000.00	4,282,601,188,270.20	3,880,445,887,230.00
30	3,498,000,000,000.00	45,000,000.00	4,430,277,091,314.00	4,014,254,366,100.00
31	3,614,600,000,000.00	46,500,000.00	4,577,952,994,357.80	4,148,062,844,970.00
32	3,731,200,000,000.00	48,000,000.00	4,725,628,897,401.60	4,281,871,323,840.00
33	3,847,800,000,000.00	49,500,000.00	4,873,304,800,445.40	4,415,679,802,710.00
34	3,964,400,000,000.00	51,000,000.00	5,020,980,703,489.20	4,549,488,281,580.00
35	4,081,000,000,000.00	52,500,000.00	5,168,656,606,533.00	4,683,296,760,450.00
36	4,197,600,000,000.00	54,000,000.00	5,316,332,509,576.80	4,817,105,239,320.00
37	4,314,200,000,000.00	55,500,000.00	5,464,008,412,620.60	4,950,913,718,190.00
38	4,430,800,000,000.00	57,000,000.00	5,611,684,315,664.40	5,084,722,197,060.00
39	4,547,400,000,000.00	58,500,000.00	5,759,360,218,708.20	5,218,530,675,930.00
40	4,664,000,000,000.00	60,000,000.00	5,907,036,121,752.00	5,352,339,154,800.00
41	4,780,600,000,000.00	61,500,000.00	6,054,712,024,795.80	5,486,147,633,670.00
42	4,897,200,000,000.00	63,000,000.00	6,202,387,927,839.60	5,619,956,112,540.00
43	5,013,800,000,000.00	64,500,000.00	6,350,063,830,883.40	5,753,764,591,410.00
44	5,130,400,000,000.00	66,000,000.00	6,497,739,733,927.20	5,887,573,070,280.00
45	5,247,000,000,000.00	67,500,000.00	6,645,415,636,971.00	6,021,381,549,150.00
46	5,363,600,000,000.00	69,000,000.00	6,793,091,540,014.79	6,155,190,028,020.00
47	5,480,200,000,000.00	70,500,000.00	6,940,767,443,058.59	6,288,998,506,890.00
48	5,596,800,000,000.00	72,000,000.00	7,088,443,346,102.39	6,422,806,985,760.00
49	5,713,400,000,000.00	73,500,000.00	7,236,119,249,146.19	6,556,615,464,630.00
Final	5,830,000,000,000.00	75,000,000.00	7,383,795,152,189.99	6,690,423,943,500.00

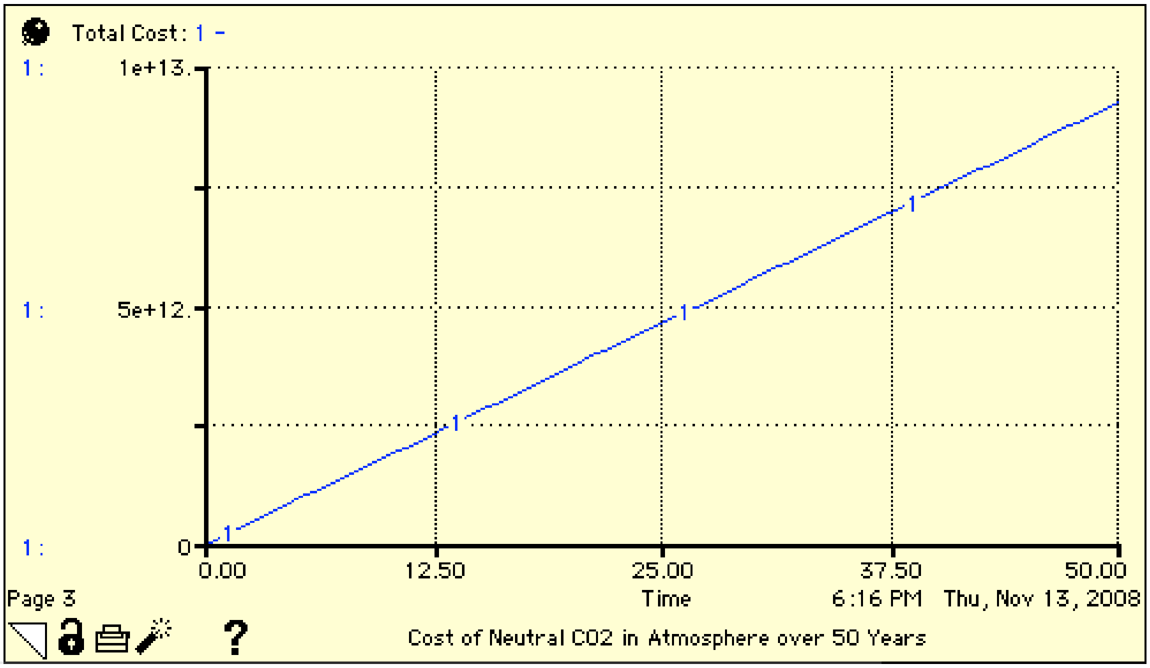
Appendix C4


1 : CO2 in Atmosphere
1 :
770
1 :
765
1 :
760
0.00
12.50
25.00
37.50
50.00
Time
Page 7
5:10 PM Thu, Nov 13, 2008
Carbon Emissions and Consumption Neutrality

Time	C02 in Atmo
25	830.73
26	833.36
27	835.99
28	838.62
29	841.25
30	843.88
31	846.51
32	849.14
33	851.77
34	854.40
35	857.03
36	859.66
37	862.29
38	864.92
39	867.54
40	870.17
41	872.80
42	875.43
43	878.06
44	880.69
45	883.32
46	885.95
47	888.58
48	891.21
49	893.84
Final	896.47

25	765.00
26	765.00
27	765.00
28	765.00
29	765.00
30	765.00
31	765.00
32	765.00
33	765.00
34	765.00
35	765.00
36	765.00
37	765.00
38	765.00
39	765.00
40	765.00
41	765.00
42	765.00
43	765.00
44	765.00
45	765.00
46	765.00
47	765.00
48	765.00
49	765.00
Final	765.00

Appendix C5


Total Cost: 1 -
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1: 5e+12
1: 0
0.00
12.50
25.00
37.50
50.00
Page 3
Time
6:16 PM Thu, Nov 13, 2008
Cost of Neutral CO2 in Atmosphere over 50 Years

Time	Total Cost
0	0.0
1	139,357,805,759.2
2	278,715,611,518.5
3	418,073,417,277.8
4	557,431,223,037.1
5	696,789,028,796.4
6	836,146,834,555.7
7	975,504,640,315.0
8	1,114,862,446,074.3
9	1,254,220,251,833.6
10	1,393,578,057,592.9
11	1,532,935,863,352.1
12	1,672,293,669,111.4
13	1,811,651,474,870.7
14	1,951,009,280,630.0
15	2,090,367,086,389.3
16	2,229,724,892,148.6
17	2,369,082,697,907.9
18	2,508,440,503,667.2
19	2,647,798,309,426.5
20	2,787,156,115,185.8
21	2,926,513,920,945.0
22	3,065,871,726,704.3
23	3,205,229,532,463.6
24	3,344,587,338,222.9
25	3,483,945,143,982.2

Time	Total Cost
25	3,483,945,143,982.
26	3,623,302,949,741.
27	3,762,660,755,500.
28	3,902,018,561,260.
29	4,041,376,367,019.
30	4,180,734,172,778.
31	4,320,091,978,537.
32	4,459,449,784,297.
33	4,598,807,590,056.
34	4,738,165,395,815.
35	4,877,523,201,575.
36	5,016,881,007,334.
37	5,156,238,813,093.
38	5,295,596,618,853.
39	5,434,954,424,612.
40	5,574,312,230,371.
41	5,713,670,036,130.
42	5,853,027,841,890.
43	5,992,385,647,649.
44	6,131,743,453,408.
45	6,271,101,259,168.
46	6,410,459,064,927.
47	6,549,816,870,686.
48	6,689,174,676,445.
49	6,828,532,482,205.
Final	6,967,890,287,964.

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