Summary

The authors approached the presented problem as a synthesis of three interrelated issues: the most cost-effective method of post-CCS storage, the economics of a complete conversion to said method, and the possibility of achieving carbon neutrality in the U.S.

After evaluating four methods of post-CCS storage with respect to cost per volume of CO_2 captured, long-term leakage rate, and environmental hazards, the authors determined that geosequestration is undoubtedly the most cost-effective. After verifying that geosequestration is the best method of CO_2 consumption, the authors focused upon how the government could feasibly subsidize a conversion of all power plants to CCS and geosequestration capabilities, with the lowest adverse economic and cultural costs.

The authors created a Java program which calculates the total cost which the government must subsidize, after the user inputs the number of years in which a complete conversion to CCS capabilities must take place, the increase in percent of the subsidy funded by tax revenue, and if the Enhanced Oil Recovery method will be used. Given the percent of the subsidy that will be funded by tax revenue in a specified year, the program then calculates the tax per capita and the remaining amount that will funded by the government through loans (and thus added to the national debt).

The authors determined that a gradual increase in taxes over a span of several years would be the best manner in which to diffuse the cost burden while maintaining a relatively healthy economy. The time span allows for technological advances, which increase efficiency and reduce prices. With current technology, the U.S. is unable to be carbon-neutral. Carbon emissions greatly outweigh consumption in all models considered by more than three billion tons.

Members of United States Congress
United States Capitol
Capitol Hill
Washington, DC 20515

Members of United States Congress,

Our committee has created a model to help the United States reach a carbon footprint of zero. Instead of trying to reduce carbon dioxide emissions, our model uses the method of carbon consumption to reduce our carbon footprint. After evaluating several different methods of carbon dioxide capture and storage our committee has determined the most cost effective method would be to use a carbon capture system (CCS) at power plants and then store the carbon dioxide using a method called geosequestration. Geosequestration is a technique that has already been developed and in use at several power plants world-wide. Geosequestration has the added benefit that when carbon dioxide gas is added to an oil well, more oil can be extracted in a method called enhanced oil recovery or EOR.

The increase of electricity costs would be substantial if all power was converted to CCS technology immediately, or even over time. Our committee suggests that the government subsidize any increase in electricity production costs to keep the price for consumers the same. This subsidy could then be paid for with a gradual increase in taxes. To account for this, our committee has developed a computer program that allows the user to input how quickly all power plants would be converted to CCS, whether or not EOR technology is to be applied, what percentage of the total subsidy amount would be transferred to citizens. With these inputs, the program then gives a year by year analysis of the increased cost of taxes per capita, and a total amount of money spent over the entire course of the tax program.

The advantages of this computer model are that you as Congress members have the option to choose what kind of program you would implicate according to varying economic conditions within the country. This flexibility is one of the major advantages of our model.

If the goal of the United States Congress is to create a carbon neutral nation, we believe that our method would be an excellent tool in reaching this goal.

Sincerely,

Advisory Committee 2075

CARBON NEUTRALITY AND CARBON CONSUMPTION

A Mathematical Model to Evaluate the Varied Effects of Carbon Consumption

Table of Contents

1.0 Introduction

1.1 Analysis of the Question

The authors were challenged to determine if there is a feasible manner in which the U.S. can approach carbon neutrality by increasing carbon dioxide consumption, considering the economic and cultural impacts. They have set out to create the most practical and cost-effective method of carbon consumption and then determine the cultural and economic impacts of said method, as well the new carbon footprint of U.S. society. The authors have decided to specifically focus this investigation on the least adverse manner in which to finance a complete conversion to carbon consumption technology.

1.2 Variables

After analyzing the question, the authors chose the following variables as the most relevant and having the most bearing upon the creation of an accurate model:

- **Method of storage:** The type of post-CCS storage plays a very large role in the effectiveness of the solution. The cost, long-term effectiveness and environmental effects of the method vary greatly between options.
- **Time of conversion:** The conversion timeline mandated by the government will affect the magnitude of immediate impact on the economy. A conversion over a short time period would be more likely to cause damaging inflation than a more gradual approach.
- **Taxes or debt:** The government can determine the amount of the subsidy they will finance with tax revenue. The remaining value would be added to the national debt. This amount will greatly affect the economic impact of the plan. The model

also includes the option of gradually increasing the amount of subsidies paid for with taxes over a given time period.

1.3 Constants

The authors elected to hold several time-dependent variables constant to make the model more reliable. In order to eliminate the uncertainty caused by change over time, the following factors were held constant:

- **Electricity consumption within the U.S.:** At current levels, Americans use 29.30 trillion kilowatt-hour (kWh) of electricity each year; 25.003 trillion kWh result from the combustion of fossil fuels. This produces a total of 2.8 billion tons of carbon dioxide annually. These numbers were used in calculations regardless of change in time.
- **Power production ratio:** Currently, 26.39% of the U.S.'s power from fossil fuels is derived from coal and 26.40% from natural gas.[8] These two numbers were used in the calculation of change in cost per Kwh of converting to CCS power plants in order to allow for a more accurate representation of power within America.
- **U.S. population:** The population of the United States is assumed remain constant at the July 2008 level of 303,824,640.[7] This is necessary to calculate the amount of tax per capita.

1.4 Justification of Assumptions

The authors feel that all of the following assumptions are relevant and were necessary in order to create an applicable model:

- **CO_2 emissions level:** As prompted by the question, the authors assumed that the U.S. CO_2 emission levels remained at its 2007-2008 cap level. This simplified the model by allowing the authors to analyze the direct effects of increased consumption.

- **Familiarity of topic:** The authors assumed that the readers are familiar with carbon capture and storage and various methods of carbon dioxide consumption. This prior knowledge is necessary in order to fully understand the model developed by the author.
- **Adequate and satisfactory sequestering locations:** The authors assumed that there will be sufficient space underground in which to sequester the carbon dioxide until further technology develops. Due to the current lack of a legitimate estimate of the amount of open volume under the U.S.'s surface, the authors were unable to account for the inevitable exhaustion of space. The authors also assumed that the sequestering locations would not harm native organisms, limiting the negative environmental effects.
- **Technological advancement:** In order to simplify the model (and because data is currently nonexistent) the authors assumed that research and development would not result in increased efficiency and decreased cost of current CCS methods over the course of the models used. Technological advance, like exhaustion of space, is inevitable, but since the rate at which this would proceed is highly variable and currently unknown, the authors decided to omit this variable from their equations.

2.0 Method

The authors decided to analyze the problem with respect to three separate questions:

1. What methods of carbon dioxide consumption are most effective, in terms of cost and actual amount of carbon dioxide consumed?
2. Under what circumstances would the conversion to CCS plants be the least economically adverse?
3. Is carbon neutrality even possible in the United States?

The authors researched current methods of post-CCS storage that are logistically able to be implemented. Then they created and analyzed a chart of each of the four methods with respect to the short-term cost, long-term effectiveness, and environmental disadvantages. The authors also produced a computer program that would allow future U.S. policymakers to manipulate a variety of variables that affect the economic impact of the conversion to increased carbon consumption. The possibility of carbon neutrality or reducing the carbon footprint of the United States was discussed by comparing its carbon dioxide emissions and consumption.

2.1 Comparison of Methods of Post-CCS Storage

The authors gathered the following information about current types of CO_2 storage:

Method of Storage (after CCS)	**Cost per Ton of CO_2 Consumed (in US Dollars, Includes Costs of CO_2 Capture and Transport)**	**% of CO_2 Leakage in the Long-Term**	**Disadvantages and Negative Environmental Effects**
Geosequestration	\$38 [4]	1% over 1000 years [3]	
Geosequestration with Enhanced Oil Recovery	\$10-\$16 net profit per ton [5]	1% over 1000 years [3]	-Increase in oil production may negate positive effects of CO_2 consumption [3]
Submarine Sequestration	\$40-\$80 [3]	15% to 70% percent over 500 years [3]	-Can cause acidification of oceans [3]

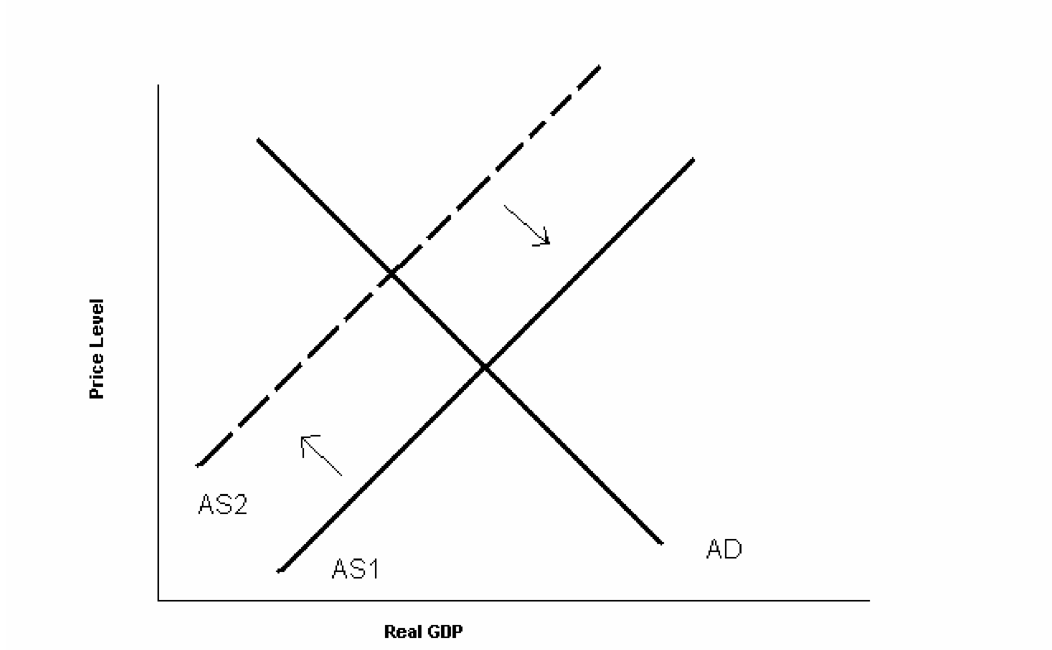
Mineral Conversion	\$50 to \$100 [6]	0% [6]	-Requires 60%-180% more energy to convert at power plants [6] -Has the negative environmental effects of a large-scale mining industry [6]

Upon a cognitive analysis of this information, the authors determined that geosequestration—with or without enhanced oil recovery—would be the most viable option, in relation to cost-effectiveness and storage reliability. The methods were evaluated on the cost per ton of CO_2 captured and the rate of leakage in the long-run. Submarine sequestration and mineral conversion are not only more expensive than geosequestration, but they also involve adverse environmental effects that would negate the good done by carbon capture. For these reasons, the authors chose to use geosequestration in following evaluations

2.2 Economic Impact

After concluding that geosequestration is the best method of carbon consumption, the authors looked for the most economically feasible way to implement these expensive changes. The authors decided that, instead of requiring an immediate conversion, the government should mandate an annual increase in the percentage of power produced in plants capable of CCS and geosequestration until all power plants are capable. This eventual conversion limits the damaging economic effects by keeping the annual costs relatively low.

Figure 2.2.1: Effects of CCS Conversion on Electrical Market



The increased cost of CCS conversion would cause a related increase in the production costs of most goods; the aggregate supply curve would shift left from AS1 to AS2, as seen in Figure 1. To alleviate the increased energy prices due to the upward movement of the market's AS curve, the government should subsidize the additional cost of power. The correction of the underallocation of resources would return the AS2 curve to its original position, AS1, thereby keeping the price of power constant for consumers, while increasing carbon dioxide consumption[2].

To finance the subsidies, the government could collect more taxes or borrow the money and increase the national debt. The government would not be able to finance the subsidy because it simply could not handle such a large increase to the national debt. Conversely, if the government immediately passed the entire burden onto the public, consumers would struggle and aggregate demand would decrease sharply, resulting in a recession.

To apply a scalar analysis to the question of subsidies, the authors created a series of equations to model how the amount the government would have to subsidize to stay at optimal levels. The first is a general equation to calculate the subsidy amount.

1.) $\frac{\Delta \text{cost}}{\text{kWh}} * \text{kWh}_{\text{ccs}} =$ The amount the government has to subsidize

The second equation uses information about the change in cost of CCS methods per kWh in coal and natural gas plants[5], and multiplies this by the amount of either gas or coal consumed, as a percentage of all fossil fuels[8]. You end up with the change in cost per kWh.

2.) $\frac{\Delta \text{cost}}{\text{kWh}} = (\$.02925 * .2639) + (\$.0205 * .2640) = \$.013131075$

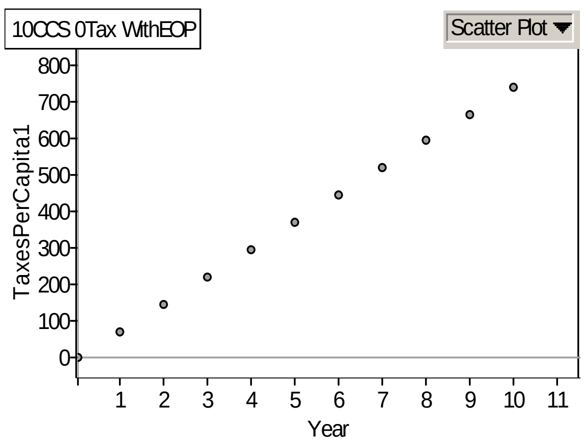
The third equation uses a similar method as the second, but the costs have been adjusted to account CCS with EOR[5].

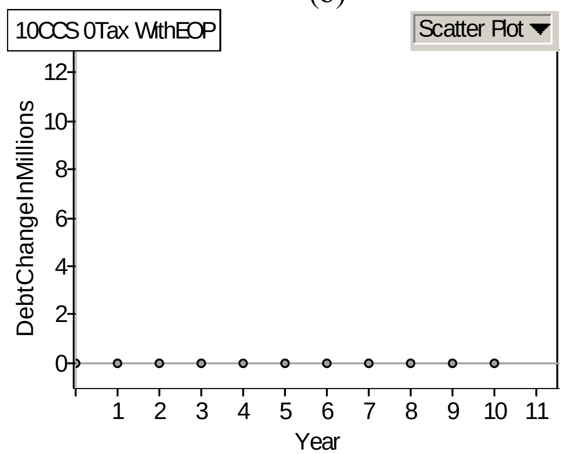
3.) $\frac{\Delta \text{cost}}{\text{kWh}}_{EOR} = (\$.021 * .2639) + (\$.013 * .2640) = \$.0089739$

Using equations 2 and 3, the authors then wrote a program to simulate the economy given a projected time to complete converting all power plants and with a specific tax increase. It returns the total monetary value added to the national debt, and the per capita tax for each year. See Section 3.0, Program Description, for a further description of the program.

Figure 2.2.2

(a) (b)



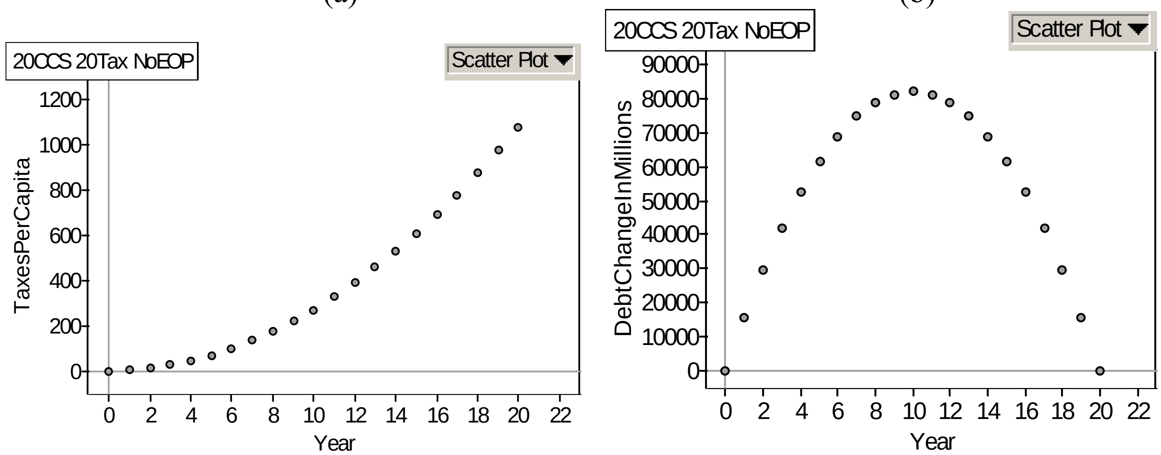


These graphs show the case where the government puts the entire cost of the subsidies into taxes, as CCS use increases over a period of ten years. The first graph shows the tax per person for each of the ten years, while the second graph shows how no debt is accumulated by the government. (See Appendix C for all actual data represented in a table)

In the model, the rate of increase in taxes and amount of power produced in CCS plants can be chosen independently, based on the given economic situation and the resultant goals and worries of the government. Increasing carbon consumption requirements more quickly than taxes would increase the total debt accumulated, but would dampen the immediate adverse economic effects. This is also optimal for reducing CO_2 as quickly as possible.

Figure 2.2.3

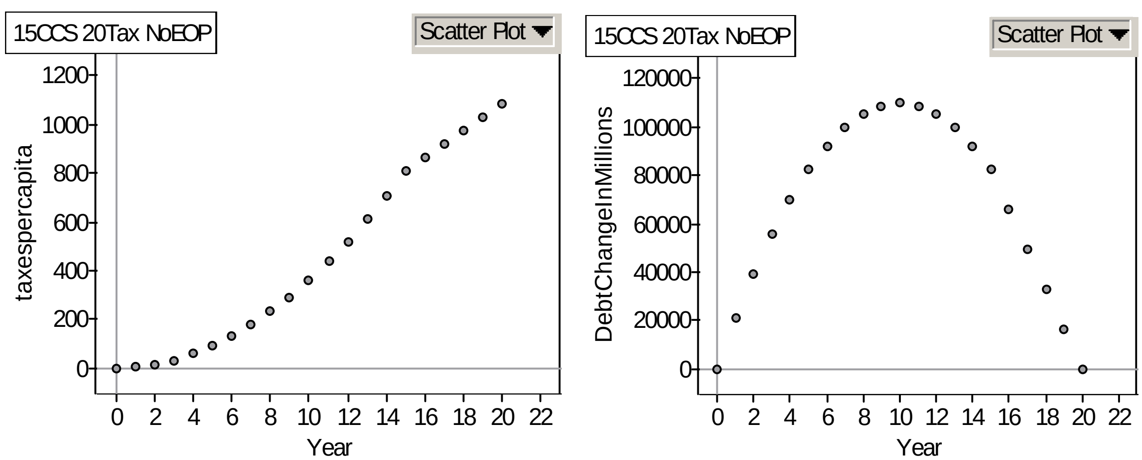
(a) (b)



These graphs show the outcome in the case where CCS and taxes both go to 100% over the course of 20 years, without utilizing EOR. The taxes increase more towards the end of the time period, which could cause a problem for taxpayers. The government deficit increases to \$82177.6 million, but then decreases back to \$0.

Figure 2.2.4

(a) (b)



In this case, all power plants are converted after fifteen years, but the taxes take twenty years to reach 100%. This means that the tax increase per year becomes constant after year 15, instead of continuing to get steeper which could lighten the burden on taxpayers. However, this also increases the cost to the government.

2.3 Carbon Neutrality

The authors then addressed the question of carbon neutrality and determined the carbon footprint of the U.S., with the knowledge that:

- The U.S. produces a total of 6.05 billion tons of carbon dioxide each year[8].
- Of the total carbon dioxide produced, the total produced through electricity generation is 2.8 billion tons[8].
- CCS is efficient only to a maximum of 90%[3].
- Forests sequester an average of 309 million tons of carbon dioxide annually[1].

$$6.05-(.9*2.8)-.309=3.221 \text{ billion tons}$$

This number shows that even with the most efficient and advanced CCS systems, carbon neutrality would not be possible. In order for the United States to reach carbon neutrality, carbon dioxide sequestration by trees and other organisms would have to be increased by reforestation, and other sources of carbon emissions would have to be reduced.

3.0 Program Description

INPUT

- Change in percent of plants converted to CCS each year --or-- Number of years until all power plants have CCS.
- Change in percent of budget for subsidizing CCS comes from taxes --or-- Number of years until budget is completely accounted for by taxes
- Whether or not enhanced oil recovery is used
- Whether or not to output results in a table or in a sentence format

OUTPUT

- Table or series of sentences containing year, percent of subsidization paid by taxes, percent of power plants with CCS, millions of dollars needed for subsidization, taxes per capita going to subsidization, and national debt change in millions of dollars for each year.

VARIABLES

- Constants
  - Increase of the cost of a kilowatt if oil is not enhanced
  - Increase of the cost of a kilowatt if oil is enhanced
  - Population of US
  - Annual kilowatt usage
- User input
  - Change in percent of plants converted to CCS each year
  - Number of years until all power plants have CCS
  - Change if percent of budget for subsidizing CCS coming from taxes
  - Number of years until budget is completely accounted for by taxes
  - Whether or not enhanced oil recovery is used
  - Whether or not to output results in a table
- Calculated Data
  - How many years have gone by
  - Dollars needed for subsidization
  - Total tax amount put on public
  - Tax amount put on each individual person

- Change in national debt each year

Step 1: Set up constants (population, annual kilowatt usage, increased cost of kilowatt usage with or without oil enhancement).

Step 2: Ask user for a series of inputs and store the inputs in their designated variables

Note: Since some user inputs are directly related to other user inputs, only four of the six variables need be inputted. The other must be calculated.

Step 3: Calculate user input variables not given by user.

Step 4: Initialize year to 0.

Step 5: Calculate necessary info for year.

Step 6: Print info in designated format.

Step 7: Increment year by 1.

Step 8: Repeat Steps 5 through 7 until all power plants have CCS *and* subsidization entirely accounted for by taxes.

Step 9: Do steps 5 through 7 once more with all power plants having CCS and subsidies completely financed by taxes.

4.0 Final Analysis

4.1 Strengths

- The model was based on a clear understanding of economic principles, such as the effects of subsidies. This understanding resulted in a more practical and applicable model, to the government if it were to impose our plan.
- The model lends itself to the analysis of differing tax schedules through the creation and side-by-side comparison of graphs.

- The tax-debt model allows for almost infinite amount of possible tax schedules and debt accumulations. This would offer the government an incredible amount of flexibility in determining the best course of action to take, with respect to various possible economic conditions.

4.2 Weaknesses

- The model cannot account for the inevitable change in international and/or domestic circumstances which would alter the economy, and thus alter the tax rate and national debt. It also doesn't account for the technological advances which would lower production costs and reduce the value of the government subsidy.
- The authors only applied their tax-debt model to geosequestration, although there are several other proposed methods of carbon dioxide consumption.
- The model does not address environmental factors, such as the carbon sequestration by trees or other plants, because the authors felt that inclusion of such variables would necessitate the creation of another model to the effects of increased natural sequestration. This model would be highly theoretical and would only further increase costs.

4.3 Conclusions

After assessing the value of various forms of carbon dioxide consumption, the authors have concluded that geosequestration is the best method in relation to cost-effectiveness and the possibility of environmental hazards.

After creating and evaluating a model, the authors decided that an annually fluctuating combination of taxes and debt accumulation would provide the most logical and feasible plan. They believe a gradual increase in taxes (and inversely, a decrease in federal spending) would be the most responsible manner in which to diffuse the burden, while managing the national debt and keeping the economy relatively healthy. Spreading the cost over many years would also allow for technological advances, which would increase efficiency and reduce prices.

The authors also considered the cultural impact of any new CCS methods adopted. Beyond the simple fact that reducing the United States' carbon footprint would be valuable to every citizen, the model has created some other impacts. The model, no matter how it is executed, is going to ask taxpayers to pay steadily increasing levels of taxes to pay for a switch to CCS technology. This would obviously be unpopular with some segments of the population, and which is why the model is centered on government control. The government is much better equipped to handle frustration than companies, and therefore better equipped to make the conversion.

Another cultural and economic impact is the creation of new jobs within the CCS sector. Though many of the jobs necessary to complete a CCS project already exist within the power, oil, and mining industries, the increased magnitude of projects would require more people to fulfill requirements, including monitoring. The creation of new jobs would lower the nation's unemployment, and increased income could help offset the burden of taxes.

After considering both economic and cultural impacts, the authors feel that they have created a well-founded and feasible model that is able to supply practical results.

5.0 Works Cited

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[4]Cook, Peter J. "Inquiry into Geosequestration." 14 November 2008. <http://www.aph.gov.au/house/committee/scin/geosequestration/subs/sub36.pdf>.

[5]Herzog, et al. "Special Report on Carbon Dioxide Capture and Storage: Chapter 8." 14 November 2008. <http://arch.rivm.nl/env/int/ipcc/pages_media/SRCCS-final/SRCCS_Chapter8.pdf>.

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[7]"The World Factbook: United States." 14 November 2008. <https://www.cia.gov/library/publications/the-world-factbook/print/us.html>.

[8]"U.S. Energy Consumption by Energy Source." 14 November 2008. <http://www.eia.doe.gov/cneaf/solar.renewables/page/prelim_trends/table1.pdf>.

6.0 Appendices

Appendix A: Program Code

```
import java.util.Scanner;

public class MathModeling
{
    //Cost increases are in dollars
    final static double IncreasedCostPerkWh = .013131075;   // Cost of 1 kilowatt coming form regular oil
    final static double EnhancedCostPerkWh = .0089739;      // Cost of 1 kilowatt coming from enhanced oil
    final static int POPULATION = 303824640;                // Number of people in the United States
    final static double kWhUsedAnnually = 25033000;         // Millions of kilowatts used every year
    /*
     * The purpose of this program is to calculate:
     *      how much it will cost to completely subsidize power plants usage of CCS
     *      how much of the plan can be paid for by a tax increase
     *      how much of the plan will come from adding on to the national debt
     */
     public static void main()
    {
        // Scanner is an outside program used to read user input
        Scanner in = new Scanner(System.in);

        // annual increase in power plants with CCS
        double percentIncreaseInKWH;
        // years it will take to convert all power plants to CCS
        double yearsToConvert;

        // Asks user to choose which type of input he/she wants
        System.out.println("Do you want to give (1) the number of years to convert");
        System.out.println("                 or (2) the percent converted each year?");
        String decision = null;

        // loop will continue until decision equals either 1 or 2, at which point it will break from the loop
        while (true)
        {
            // Note:
            // (percent of power plants converted each year) * (years taken to convert) = to 100 percent
            // percentIncreaseInKWH * yearsToConvert = 100

            // waits for user to press a key
            decision = in.next();
            // evaluates what key was pressed
            // if "1" was pressed
            if(decision.contains("1"))
            {
                // Asks for years it will take to convert all power plants to CCS
                System.out.print("Years until all plants are converted to CCS? \n:");
                // years taken to convert is inputted by user and stored
                yearsToConvert = in.nextDouble();
                // % power plants converted per year is calculated from years taken to convert
                percentIncreaseInKWH = 100.0/yearsToConvert;
                // break exits loop, not if statement
                break;
            }
            // if "2" was pressed
            if(decision.contains("2"))
            {
                // Asks for annual increase in percent of power plants converted each year
                System.out.println("Change in percentage of kilowatt hours /w CCS per year?");
                System.out.print(":");
                // percent of power plants converted each year is inputted by user and stored
                percentIncreaseInKWH = in.nextDouble();
                // number of years taken to convert everyone to CCS
                // is calculated from % power plants converted each year
                yearsToConvert = 100.0/percentIncreaseInKWH;
                break;
            }
            // if neither "1" nor "2" was pressed, the program will go back to the
            // while command. therefore, the program will continue to wait for user
            // input until the desired input is entered
        }
        // the "break;" command causes the program to jump to here

        //Note:
        // the number of years to convert to CCS can differ
        // from number of years to convert to full tax coverage

        // years it will take until subsidization is completely paid for by taxes
```

```
        double yearsToTax;
        // annual increase in percent of subsidization
        double taxPercent;

        // Note:
        // (percent of power plants converted each year) times (years taken to convert) is equal to 100%
        // percentIncreaseInKWH * yearsToConvert = 100

        // Asks user to choose which type of input he/she wants
        System.out.println("Do you want to give (1) the number of years until full tax");
        System.out.println("                  or (2) the tax increase each year?");
        // if user selects option 1 (give the number of years until tax completely subsidized CCS)
        if(in.nextInt() == 1)
        {
            // Asks for how many years until tax completely subsidizes CCS
            System.out.println("Years until full tax?");
            System.out.print(":");
            // Gets how many years it will take for tax to completely subsidize CCS and stores it
            yearsToTax = in.nextDouble();
            // Uses yearsToTax to calculate how much to increase taxes each year and stores it
            taxPercent = 100.0/yearsToTax;
        }
        // if user doesn't select option 1, option 2 is used
        // Option 2 = give the percent increase of CCS subsidization from taxes each year
        // Note: the user doesn't have to enter a 2 for option 2 to be selected
        else
        {
            // Asks for annual change in percent of CCS subsidization paid for by taxes
            System.out.println("Change in tax percentage each year?");
            System.out.print(":");
            // Gets annual change in percent of CCS subsidization paid for by taxes and stores it
            taxPercent = in.nextDouble();
            // Uses taxPercent to calculate the years it will take for taxes to completely pay for CCS
subsidization
            yearsToTax = 100.0/taxPercent;
        }

        // Asks user whether or not to use enhanced oil recovery in the calculations
        System.out.println("Do you want enhanced oil recovery? (y/n)");
        System.out.print(":");
        // Stores users input
        String s1 = in.next();
        s1 += in.nextLine();
        // if users input contained a "y", program will assume that the user
        // wants to include oil recovery in their calculations
        // Note:
        // if user inputs "happy", program will assume user wants to include
        // oil recovery calculations because "happy" contains a y
        boolean enhanced = s1.contains("y");

        // current year being examined
        int year = 0;
        // millions of dollars needed to subsidize power plants for the given year
        double result = 0;
        // total amount of money being added to the national debt in millions of dollars
        double totalDebt = 0;

        //percent of kWh made with CCS
        double converted = 0;

        // multiplier is used for calculating the money need for subsidizing CCS
        double multiplier = IncreasedCostPerkWh;
        // multiplier is dependent on whether or not the user chose to include oil enhancement
        if (enhanced)
            multiplier = EnhancedCostPerkWh;

        // i = current percent of CCS subsidization accounted for by taxes
        double i = 0;

        // asks user if information should be displayed in a format that can be copy and pasted into Fathom
        // Note: Fathom is a graphing software
        System.out.println("Do you want to copy to Fathom? (y/n)");
        System.out.print(":");
        // if user doesn't want to copy and paste into Fathom then
        if (in.nextLine().contains("n"))
        {
            // loop will display information for a given year
            // Example:
            // "Year 19 (95.0% tax and 76.0 % CCS): 249819.752361 Million Dollars
            // "  $781.13 taxes per capita  $12490.98761805001 million added to national debt.
            while ( i < 100 || converted < 100)
```

```
            {
                // i is the % to taxes
                // calculates result (money needed for subsidizing CCS in millions of dollars for the given
year)
                result = multiplier * .01 * converted * kWhUsedAnnually;
                // outputs all data
                System.out.print("Year " + year + " (" + i + "% tax and " + converted +" % CCS): ");
                System.out.print(result + " Million Dollars \n  $");
                System.out.print(round((i/100.0)*(1000000.0*result/POPULATION), 2)  + " taxes per capita  $");
                System.out.println(result * (1-(i/100.0))+ " million added to national debt.");
                // increments variable converted by variable percentIncreaseInKWH and
                // prevents converted from exceeding 100
                if(converted + percentIncreaseInKWH <= 100)
                    converted += percentIncreaseInKWH;
                else
                    converted = 100;
                // increments year by 1
                year++;
                // adds debt increase this year to total debt increase
                totalDebt += (result * (1.0 - (i/100.0)));
                // increments taxPercent and keeps it from exceeding 100
                if(taxPercent + i <= 100)
                    i += taxPercent;
                else
                    i = 100;
            }

            // calculates final result
            result = multiplier * kWhUsedAnnually;
            // Displays results when taxes completely pays for CCS subsidization and all power plants have CCS
            System.out.print("Year " + year + " (" + 100 + "% tax and " + converted + " % CCS): ");
            System.out.print(result + " Million Dollars \n  $");
            System.out.print(round((i/100.0)*(1000000.0*result/POPULATION), 2) + " taxes per capita  $");
            System.out.println(0.0 + " million added to national debt.");
            // increments year by 1
            year++;
            // adds debt increase this year to total debt increase
            totalDebt += (result * (1.0 - (i/100.0)));

            // displays total debt in millions
            System.out.println("Total Debt: $" + totalDebt + " Million added to the National Debt");
        }
        else
        {
            char tab = ' ';
            String label = "Year<tab>%tax<tab>%CCS<tab>Mill
Dollars<tab>TaxesPerCapita<tab>DebtChangeInMillions";
            label = label.replace("<tab>", "" + tab);
            System.out.println(label);
            // year     %tax    %CCS    Mill Dollars    taxes per capita    added to debt;

            // done will be changed to true once taxes pays for all of CCS subsidization in all power plants
            boolean done = false;

            // repeat until done = true
            while (!done)
            {

                if ( i >= 100 & converted >= 100) done = true;

                //i is the % to taxes
                //in millions, the money spent for the year
                result = multiplier * .01 * converted * kWhUsedAnnually;
                System.out.print(round(year, 2) + tab + round(i, 2) + tab);
                System.out.print(round(converted, 2) + tab + round(result, 2) + tab);
                System.out.print(round((i/100.0)*(1000000.0*result/POPULATION), 2) + tab);
                System.out.println(round(result * (1-(i/100.0)), 2));
                // increments variable converted by variable percentIncreaseInKWH and
                // prevents converted from exceeding 100
                if(converted + percentIncreaseInKWH <= 100)
                    converted += percentIncreaseInKWH;
                else
                    converted = 100;
                // increments year by 1
                year++;
                // adds debt increase this year to total debt increase
                totalDebt += (result * (1.0 - (i/100.0)));
                // increments taxPercent and keeps it from exceeding 100
                if(taxPercent + i <= 100)
                    i += taxPercent;
                else
```

```
                i = 100;
            }
        }

    }
    /*
     * String round(double num, int amount)
     * Inputs:
     *      num         number you want turned into a string
     *      amount      number of decimals after the (.) you want to see
     * Outputs:
     *      returns a string representative of the number
     * Example:
     *      round(3.3333333333, 2)
     *      return "3.33"
     */
    private static String round(double num, int amount)
    {
        // turn your number into a string
        String x = num + "";
        // find the (.) in the string
        int place = x.indexOf('.');
        try
        {
            // cuts string off (amount) places after the (.)
            return x.substring(0, place + amount + 1);
        }
        catch (Exception ex)
        {
            // if (numbers actually after the (.)) < (numbers you want to be after the (.))
            // then an error will form and you just want to return the original number
            //
            // example: num = 14.5, amount = 3
            // x = "14.5"
            // can't take the string 3 after the (.) b/c there's nothing there
            // return 14.5
            return x;
        }
    }
}
```

Appendix B: Sample Program Output

Program output* example 1

```
Do you want to give (1) the number of years to convert
                 or (2) the percent converted each year?
:1
Years until all plants are converted to CCS?
:14
Do you want to give (1) the number of years until full tax
                 or (2) the tax increase each year?
:2
Change in tax percentage each year?
:9
Do you want enhanced oil recovery? (y/n)
:y
Do you want to copy to Fathom? (y/n)
:y
Year   %tax   %CCS   Mill Dollars   TaxesPerCapita    DebtChangeInMillions
0.0    0.0    0.0    0.0            0.0               0.0
1.0    9.0    7.14   16045.97       4.75              14601.83
2.0    18.0   14.28  32091.94       19.01             26315.39
3.0    27.0   21.42  48137.92       42.77             35140.68
4.0    36.0   28.57  64183.89       76.05             41077.69
5.0    45.0   35.71  80229.87       118.82            44126.42
6.0    54.0   42.85  96275.84       171.11            44286.88
7.0    63.0   50.00  112321.81      232.90            41559.07
8.0    72.0   57.14  128367.79      304.20            35942.98
9.0    81.0   64.28  144413.76      385.00            27438.61
10.0   90.0   71.42  160459.74      475.31            16045.97
11.0   99.0   78.57  176505.71      575.13            1765.05
```

```
12.0   100.0  85.71  192551.69      633.75           0.0
13.0   100.0  92.85  208597.66      686.57           0.0
14.0   100.0  99.99  224643.63      739.38           0.0
15.0   100.0  100.0  224643.63      739.38           0.0
```

Program output* example 2

```
Do you want to give (1) the number of years to convert
                 or (2) the percent converted each year?
:2
Change in percentage of kilowatt hours /w CCS per year?
:9
Do you want to give (1) the number of years until full tax
                 or (2) the tax increase each year?
:1
Years until full tax?
:20
Do you want enhanced oil recovery? (y/n)
:n
Do you want to copy to Fathom? (y/n)
:n
Year 0 (0.0% tax and 0.0 % CCS): 0.0 Million Dollars
  $0.0 taxes per capita  $0.0 million added to national debt.
Year 1 (5.0% tax and 9.0 % CCS): 29583.91804275 Million Dollars
  $4.86 taxes per capita  $28104.7221406125 million added to national debt.
Year 2 (10.0% tax and 18.0 % CCS): 59167.8360855 Million Dollars
  $19.47 taxes per capita  $53251.05247695 million added to national debt.
Year 3 (15.0% tax and 27.0 % CCS): 88751.75412825 Million Dollars
  $43.81 taxes per capita  $75438.9910090125 million added to national debt.
Year 4 (20.0% tax and 36.0 % CCS): 118335.672171 Million Dollars
  $77.89 taxes per capita  $94668.5377368 million added to national debt.
Year 5 (25.0% tax and 45.0 % CCS): 147919.59021375 Million Dollars
  $121.71 taxes per capita  $110939.69266031249 million added to national debt.
Year 6 (30.0% tax and 54.0 % CCS): 177503.5082565 Million Dollars
  $175.26 taxes per capita  $124252.45577955 million added to national debt.
Year 7 (35.0% tax and 63.0 % CCS): 207087.42629925 Million Dollars
  $238.56 taxes per capita  $134606.8270945125 million added to national debt.
Year 8 (40.0% tax and 72.0 % CCS): 236671.344342 Million Dollars
  $311.58 taxes per capita  $142002.8066052 million added to national debt.
Year 9 (45.0% tax and 81.0 % CCS): 266255.26238475 Million Dollars
  $394.35 taxes per capita  $146440.39431161253 million added to national debt.
Year 10 (50.0% tax and 90.0 % CCS): 295839.1804275 Million Dollars
  $486.85 taxes per capita  $147919.59021375 million added to national debt.
Year 11 (55.0% tax and 99.0 % CCS): 325423.09847025 Million Dollars
  $589.09 taxes per capita  $146440.3943116125 million added to national debt.
Year 12 (60.0% tax and 100.0 % CCS): 328710.200475 Million Dollars
  $649.14 taxes per capita  $131484.08019 million added to national debt.
Year 13 (65.0% tax and 100.0 % CCS): 328710.200475 Million Dollars
  $703.23 taxes per capita  $115048.57016624999 million added to national debt.
Year 14 (70.0% tax and 100.0 % CCS): 328710.200475 Million Dollars
  $757.33 taxes per capita  $98613.06014250002 million added to national debt.
Year 15 (75.0% tax and 100.0 % CCS): 328710.200475 Million Dollars
  $811.43 taxes per capita  $82177.55011875 million added to national debt.
Year 16 (80.0% tax and 100.0 % CCS): 328710.200475 Million Dollars
  $865.52 taxes per capita  $65742.04009499999 million added to national debt.
Year 17 (85.0% tax and 100.0 % CCS): 328710.200475 Million Dollars
  $919.62 taxes per capita  $49306.53007125001 million added to national debt.
Year 18 (90.0% tax and 100.0 % CCS): 328710.200475 Million Dollars
  $973.71 taxes per capita  $32871.020047499995 million added to national debt.
Year 19 (95.0% tax and 100.0 % CCS): 328710.200475 Million Dollars
  $1027.81 taxes per capita  $16435.510023750016 million added to national
debt.
Year 20 (100% tax and 100.0 % CCS): 328710.200475 Million Dollars
  $1081.90 taxes per capita  $0.0 million added to national debt.
Total Debt: $1795743.825194925 Million added to the National Debt
```

***values following a colon are user input values**

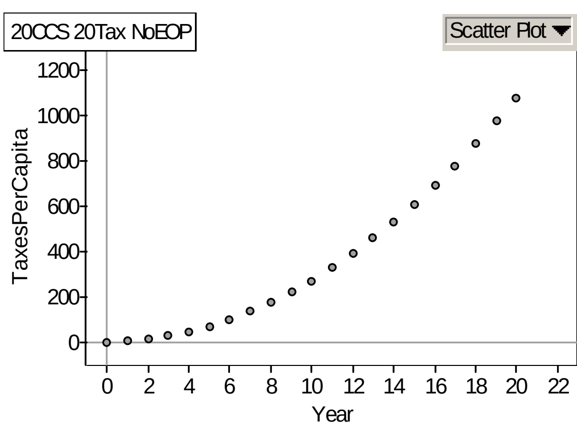
Appendix C: Data and Graphs

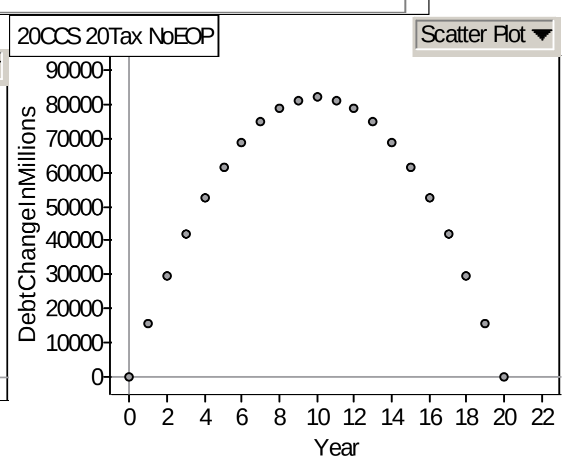
In the following examples, we show the outcomes of some of the possible plans. In the tables, the first column in the year from the start of the program, the second column is the percent of the subsidies being paid for with taxes, and the third is the percent of power produced with CCS technology. The MillDollars column is the total amount of money spent on the subsidies in that year. The final two columns show the annual tax per person and the deficit incurred by the government.

The first graph in each example shows the taxes per person over the given time period. The second shows the government deficit from the subsidies for each year.

20CCS 20Tax NoEOP

	Year	tax	CCS	MillDollars	TaxesPerCapita	DebtChangeInMillions
1	0	0	0	0	0	0
2	1	5	5	16435.5	2.7	15613.7
3	2	10	10	32871	10.81	29583.9
4	3	15	15	49306.5	24.34	41910.6
5	4	20	20	65742	43.27	52593.6
6	5	25	25	82177.6	67.61	61633.2
7	6	30	30	98613.1	97.37	69029.1
8	7	35	35	115049	132.53	74781.6
9	8	40	40	131484	173.1	78890.4
10	9	45	45	147920	219.08	81355.8
11	10	50	50	164355	270.47	82177.6
12	11	55	55	180791	327.27	81355.8
13	12	60	60	197226	389.48	78890.4
14	13	65	65	213662	457.1	74781.6
15	14	70	70	230097	530.13	69029.1
16	15	75	75	246533	608.57	61633.2
17	16	80	80	262968	692.42	52593.6
18	17	85	85	279404	781.67	41910.6
19	18	90	90	295839	876.34	29583.9
20	19	95	95	312275	976.42	15613.7
21	20	100	100	328710	1081.9	0

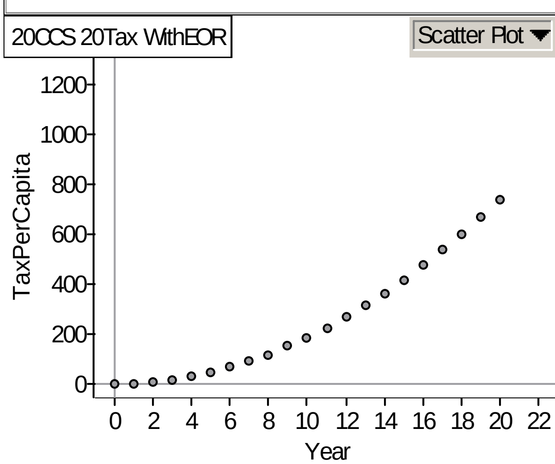


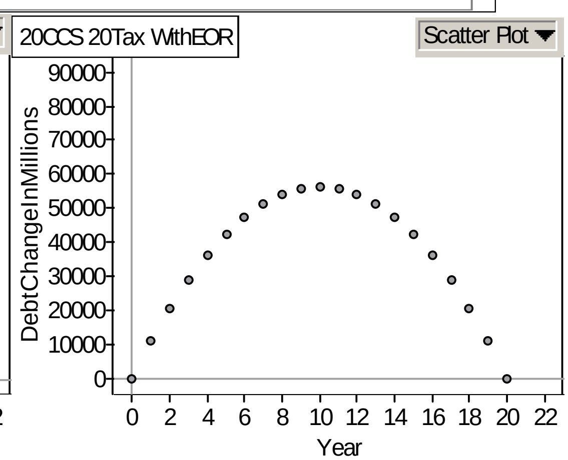


These are for the case where both taxes and CCS reach 100% after 20 years, with enhanced oil recovery. Note that the final annual tax is $1081.9 per person.

20CCS 20Tax WithEOR

	Year	tax	CCS	MillDollars	TaxPerCapita	DebtChangeInMillions
1	0	0	0	0	0	0
2	1	5	5	11232.2	1.84	10670.6
3	2	10	10	22464.4	7.39	20217.9
4	3	15	15	33696.5	16.63	28642.1
5	4	20	20	44928.7	29.57	35943
6	5	25	25	56160.9	46.21	42120.7
7	6	30	30	67393.1	66.54	47175.2
8	7	35	35	78625.3	90.57	51106.4
9	8	40	40	89857.4	118.3	53914.5
10	9	45	45	101090	149.72	55599.3
11	10	50	50	112322	184.84	56160.9
12	11	55	55	123554	223.66	55599.3
13	12	60	60	134786	266.17	53914.5
14	13	65	65	146018	312.39	51106.4
15	14	70	70	157251	362.29	47175.2
16	15	75	75	168483	415.9	42120.7
17	16	80	80	179715	473.2	35943
18	17	85	85	190947	534.2	28642.1
19	18	90	90	202179	598.9	20217.9
20	19	95	95	213411	667.29	10670.6
21	20	100	100	224644	739.38	0



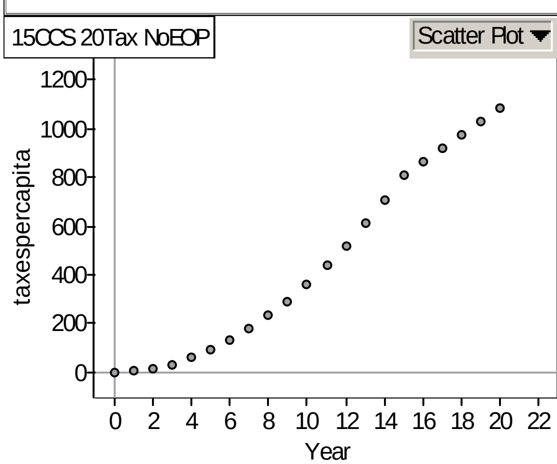


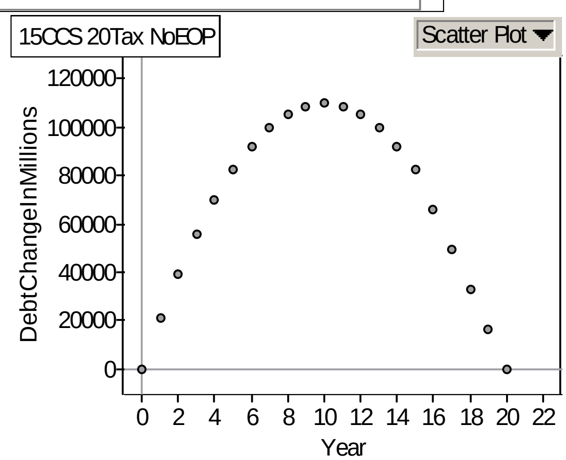
These graphs show the same plan, except with Enhanced Oil Recovery used.

Notice that the final tax is only $739.38, and the debt created is significantly smaller.

15CCS 20Tax NoEOP

	Year	tax	CCS	MillDollars	taxespercapita	DebtChangeInMillions
1	0	0	0	0	0	0
2	1	5	6.66667	21914	3.6	20818.3
3	2	10	13.3333	43828	14.42	39445.2
4	3	15	20	65742	32.45	55880.7
5	4	20	26.6667	87656.1	57.7	70124.8
6	5	25	33.3333	109570	90.15	82177.6
7	6	30	40	131484	129.82	92038.9
8	7	35	46.6667	153398	176.71	99708.8
9	8	40	53.3333	175312	230.8	105187
10	9	45	60	197226	292.11	108474
11	10	50	66.6667	219140	360.63	109570
12	11	55	73.3333	241054	436.36	108474
13	12	60	80	262968	519.31	105187
14	13	65	86.6667	284882	609.47	99708.8
15	14	70	93.3333	306796	706.84	92038.9
16	15	75	100	328710	811.43	82177.6
17	16	80	100	328710	865.52	65742
18	17	85	100	328710	919.62	49306.5
19	18	90	100	328710	973.71	32871
20	19	95	100	328710	1027.81	16435.5
21	20	100	100	328710	1081.9	0

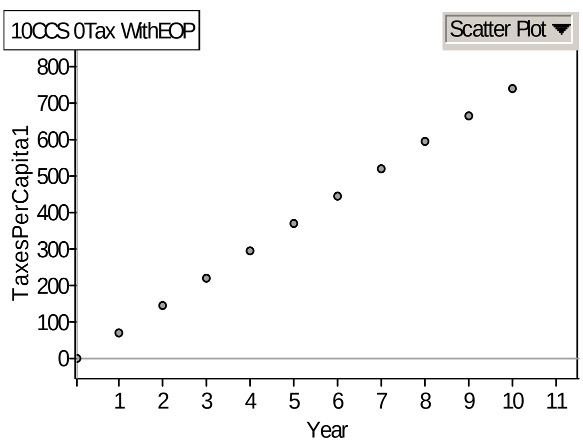


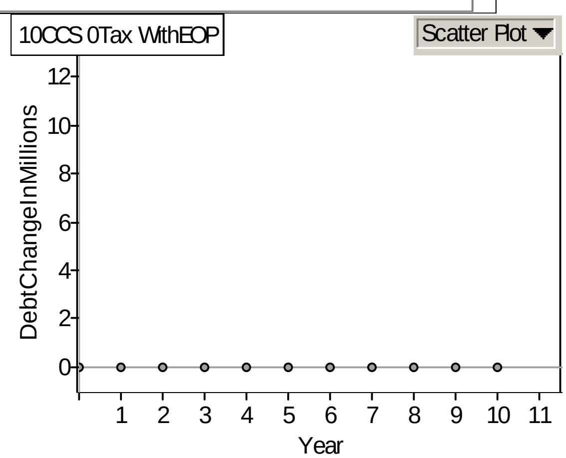


In this case, all of the plants are converted to CCS technology in fifteen years, but the tax doesn't reach 100% of the subsidized cost until twenty years. This will slightly increases the debt created. However, it also helps to eliminate the sharp increase in tax rates near the end of the conversion, as seen in the first two examples.

10CCS 0Tax WithEOP

	Year	tax	CCS	MillDollars	TaxesPerCapita1	DebtChangeInMillions
1	0	0	0	0	0	0
2	1	100	10	22464.4	73.93	0
3	2	100	20	44928.7	147.87	0
4	3	100	30	67393.1	221.81	0
5	4	100	40	89857.4	295.75	0
6	5	100	50	112322	369.69	0
7	6	100	60	134786	443.63	0
8	7	100	70	157251	517.57	0
9	8	100	80	179715	591.5	0
10	9	100	90	202179	665.44	0
11	10	100	100	224644	739.38	0





This final example puts all of the cost of conversion on the taxpayers, over a period of ten years.